Foliar Uptake of Inorganic and Organic Nitrogen Compounds by Creeping Bentgrass Putting Green Turf

Chris Stiegler[1], Mike Richardson[1], and John McCalla[1]

Additional index words: urea, potassium nitrate, ammonium sulfate, amino acids, ^{15}N

Stiegler C., M. Richardson, and J. McCalla 2009. Foliar uptake of inorganic and organic nitrogen compounds by creeping bentgrass putting green turf. Arkansas Turfgrass Report 2008, Ark. Ag. Exp. Stn. Res. Ser. 568:116-120.


Photo by Mike Richardson

Applying foliar fertilizer to a putting green

Summary. Foliar nitrogen (N) fertilization often comprises a major portion of the total N inputs applied to creeping bentgrass golf greens annually. Many of these applications are made using fertilizers that have been formulated and marketed as specialty foliar fertilizers. Various forms of inorganic and organic N are usually included in these products purchased by golf course superintendents. However, little is currently known about the foliar absorption efficiency among different chemical N forms routinely applied to putting greens. This project was conducted to evaluate foliar uptake of N after application of different ^{15}N-labeled inorganic and organic sources. Three common N fertilizer forms [(urea, ammonium sulfate ($(NH_4)_2SO_4$), and potassium nitrate (KNO_3)] were used in the trial, along with three amino acids (glycine, glutamic acid, and proline). All treatments were applied at a rate of 0.10 lb N/1000 ft^2 on 18 September 2008 to plots within a 'Penn G2' creeping bentgrass research green. Plant tissue samples were taken 1 h and 8 h after application for N analysis. Foliar uptake of the various N compounds ranged from 37-56% of the N applied at the final sampling time of 8 h after application. Nitrogen source had a significant effect on the amount of fertilizer N recovered within plant leaves/shoots. Absorption of KNO_3 into aerial plant parts was significantly lower than all of the chemical forms tested, while the other treatments were taken up similarly.

Abbreviations: KNO_3 (potassium nitrate), $(NH_4)_2SO_4$ (ammonium sulfate), $NH_2 CONH_2$ (urea), NH_4^+ (ammonium), NO_3^- (nitrate), UR (urea), AS [$(NH_4)_2SO_4$], KN (KNO_3), GLY (glycine), GLU (glutamic acid), PRO (proline)

[1] University of Arkansas, Department of Horticulture, Fayetteville, Ark. 72701

Foliar fertilization has become an increasingly common practice on golf courses around the world. While typically used as a supplement to traditional root-feeding programs, the importance of foliar fertilization has been magnified by the management practices of today's golf course superintendent. Often, this method of delivering plant nutrients makes up a large percentage of the total annual nitrogen (N) applied to golf course putting greens. Despite its prevalent use in golf course management, there have been relatively few research studies investigating foliar absorption of N by turfgrasses and no studies which document foliar uptake of nutrients in a field setting.

Urea (NH_2CONH_2), ammonium sulfate ($(NH_4)_2SO_4$), and potassium nitrate (KNO_3) are common sources of N that are water-soluble and thus can be used as foliar fertilizers. Both $(NH_4)_2SO_4$ and KNO_3 dissociate when added to water, leaving the N components in an ionic state. As is the case with root absorption, plant leaves can take up these N fertilizers as ions, more specifically ammonium (NH_4^+) and nitrate (NO_3^-). While urea stays in its original, uncharged form during mixing with water, the foliar pathway allows for direct entry of the intact urea molecule (Wittwer et al., 1963), as well as any NH_4^+-N derived from urease action on plant leaf surfaces. The previous descriptions of how these common N fertilizer sources can be utilized by plant leaves/shoots build the foundation for their inclusion within turf industry foliar products. Though these particular N fertilizers have been studied to some degree as foliar products in the turfgrass scientific literature (Bowman and Paul, 1989; Bowman and Paul, 1990), and even evaluated against each other (Bowman and Paul, 1992), no previous research has attempted to determine absorption efficiency under putting green conditions in the field.

Other small-molecular-weight organic N compounds, such as amino acids, are also often included in the various foliar fertilizer formulations currently marketed to golf course superintendents. Plants are autotrophic by nature and thus are fully capable of producing these compounds on their own, but companies claim that these amino acid additives either create a synergistic effect or can be used as chelating agents for enhanced foliar absorption of nutrients. In the assumed absence of mineralization on the turfgrass leaf surface, foliar fertilization with these amino acids would require diffusion through the plant leaf surface in the original chemical state. Therefore, regardless of the reasons behind their addition to commercially-available foliar products, these organic forms of N still need to make it into the plant to be useful. While previous horticultural research has investigated foliar absorption of amino acids using direct measurement with isotopic tracers (Furuya and Umemiya, 2002), there are no similar studies that have been specific to turfgrasses. Given the lack of research in this area, a study was initiated to directly measure foliar uptake of N supplied through different compounds, sources, and available forms of N on creeping bentgrass (*Agrostis stolonifera*) putting green turf.

Materials and Methods

This field research study was conducted at the University of Arkansas Research and Extension Center in Fayetteville, Arkansas. An experimental area of 'Penn G2' creeping bentgrass was established on a sand-based putting green (USGA, 1993) and maintained according to typical putting green management practices for the region. Within the experimental areas, three replicated plots were designated for each of the following six N source treatments: urea, $(NH_4)_2SO_4$, KNO_3, glycine, glutamic acid, and proline. The use of ^{15}N-labeled compounds enabled positive identification of fertilizer N within the plant tissue and also provided the sensitivity necessary to analyze for the small amounts of N applied to the turfgrass canopy during foliar fertilization.

Applications of all treatments were made on 18 September 2008, to 2 by 4 ft plots with 6 inch borders. Foliar N was applied in a spray volume of 58 gallons/A with the aid of a spray shield and a single nozzle CO_2-pressurized sprayer. A

Teejet® (TX-VS2) hollow cone spray nozzle was selected to produce a fine atomized spray pattern for even, thorough plot coverage facilitating foliar uptake. An application rate of 0.10 lb N/1000 ft^2 was selected for all six treatments, as this corresponds with a typical foliar N application rate used by golf course superintendents. For an 8 h period after treatment, plots received no irrigation or rainfall to limit all N absorption to the foliar uptake pathway. Plant leaf tissues were sampled at 1 and 8 h after application to examine foliar N absorption efficiency over time.

Results and Discussion

Foliar uptake was significantly affected by N source due to a reduction in uptake of one treatment. When expressed as a percentage of that which was applied to plots, all of the compounds tested were absorbed similarly, with the exception of KNO_3, which was significantly lower than the other treatments (Fig. 1). At one hour after treatment, foliar absorption efficiency across all of the N compounds ranged from 27 to 43%, while samples taken seven hours later ranged from 37 to 56%. This means that all sources of N continued to diffuse into the plant leaves/shoots over an 8 h period.

Of the commonly used fertilizer N sources, urea and $(NH_4)_2SO_4$ were both superior to KNO_3 in terms of uptake through the putting green turfgrass foliage (Fig. 1). Forty-two percent of the urea-N applied was taken up at 1 h after application and 56 % by the 8 h sampling. Fertilizer N supplied by $(NH_4)_2SO_4$ was also recovered relatively well within creeping bentgrass leaf tissue, with 40% being absorbed within 1 h and 55% at the 8 h sampling. By comparison, KNO_3-treated samples only contained 27% of the total amount of N applied at 1 h and 37% at 8 h post-treatment.

As the only source that requires uptake of N as the anion NO_3^-, the poor absorption of KNO_3 treatments is not unexpected based on previous research. The scientific consensus on how polar solutes diffuse through plant leaves is through tiny (<1 nm), hydrophilic pores that traverse the leaf cuticle (Schonherr, 1976; Marschner, 1995). These transport channels for water and small solute molecules have been reported by Tyree, et al. (1990) to be lined with negative charges. Since the NO_3^- ion also holds a negative charge, and like charges are repelled, this may explain why we observed significantly lower foliar uptake with KNO_3 when compared to NH_4^+-based N sources, like $(NH_4)_2SO_4$ or urea.

There was not a significant difference between urea and $(NH_4)_2SO_4$ in terms of recovery in plant tissue, which suggests that efficient utilization of foliar-applied N can be achieved with either source. While this is true, $(NH_4)_2SO_4$ has a higher salt index and phytotoxicity can be a problem with its use as a foliar spray. Indeed, even at the low application rate used in this study, slight yellowing of creeping bentgrass foliage was observed in plots treated with this form of N. Based on this temporary decline in visual quality when using $(NH_4)_2SO_4$ as a foliar spray, along with the previously discussed deficiencies of KNO_3, urea is a good option for foliar application on putting greens when choosing among these three N sources.

Creeping bentgrass foliage was quite receptive to all three of the amino acids tested. While proline was numerically higher in percentage foliar absorption, it was not significantly different than glutamic acid or glycine. Percentages of the labeled N supplied by proline, glutamic acid, and glycine was recovered in plant tissue 8 h after application at 52, 51, and 48% of the N delivered through spray, respectively (Fig. 1). While these pure compounds of amino acids are not to be considered as stand-alone fertilizer N sources, these data allude to direct uptake of these organic N forms by creeping bentgrass leaves when excluding the possibility of microbial transformation of amino acids on the leaf surface. The finding that amino acids can be efficiently taken up by turfgrasses, serves as a first-step in substantiating their inclusion within commercially-available foliar fertilizers. However, it should be noted that it is still not known what happens to exogenously applied amino acids once inside the plant.

The potential beneficial roles of chelation, N transport, and stress alleviation for glycine, glutamic acid, and proline, respectively, each rely on some degree of chemical stability within plant cells or the vascular system. Further research utilizing double-labeled amino acids with both ^{15}N and either ^{13}C or ^{14}C isotopes as tracers and/or more specific methodology could help answer some of these questions more conclusively.

This study has been repeated and once data are compiled we hope the results from this trial will assist golf course superintendents who wish to maximize foliar fertilization efficiency through proper selection of N form. Additionally, this research may benefit the turfgrass industry in lending scientific knowledge to companies who formulate specialty foliar fertilizers, so that they may create better products for their clientele.

Literature Cited

Bowman, D.C. and J.L. Paul. 1989. The foliar absorption of urea-N by Kentucky bluegrass turf. J. Plant Nutr. 12(5):659-673.

Bowman, D.C. and J.L. Paul. 1990. The foliar absorption of urea-N by tall fescue and creeping bentgrass turf. J. Plant Nutr. 13(9):1095-1113.

Bowman, D.C. and J.L. Paul. 1992. Foliar absorption of urea, ammonium, and nitrate by perennial ryegrass turf. J. Am. Soc. Hortic. Sci. 117(1):75-79.

Furuya, S. and Y. Umemiya. 2002. The influence of chemical forms on foliar-applied nitrogen absorption for peach trees. Proceedings of the International Seminar on Foliar Nutrition. Acta Hort., ISHS 594:97-103.

Marschner, H. 1995. Uptake and release of mineral elements by leaves and other aerial plant parts. p. 116-128. *In* Mineral Nutrition of Higher Plants. Academic Press Inc., Sand Diego, Calif.

Schonherr, J. 1976. Water permeability of isolated cuticular membranes: the effects of pH and cations on diffusion, hydrodynamic permeability and size of polar pores in the cutin matrix. Planta 128:113-126.

Tyree, M.T., T.D. Scherbatskoy, and C.A. Tabor. 1990. Leaf cuticles behave as asymmetric membranes. Evidence of diffusion potentials. Plant Phyiol. 92(1):103-109.

Wittwer, S.H., M.J. Bukovac, and H.B. Tukey. 1963. Advances in foliar feeding of plant nutrients. p. 429-455. *In* M.H. McVickar (ed.) Fertilizer Technology and Usage. SSSA Publishers, Madison, WI.

USGA. 1993. USGA recommendations for putting green construction. USGA Green Section Record. 31(2):1-3.

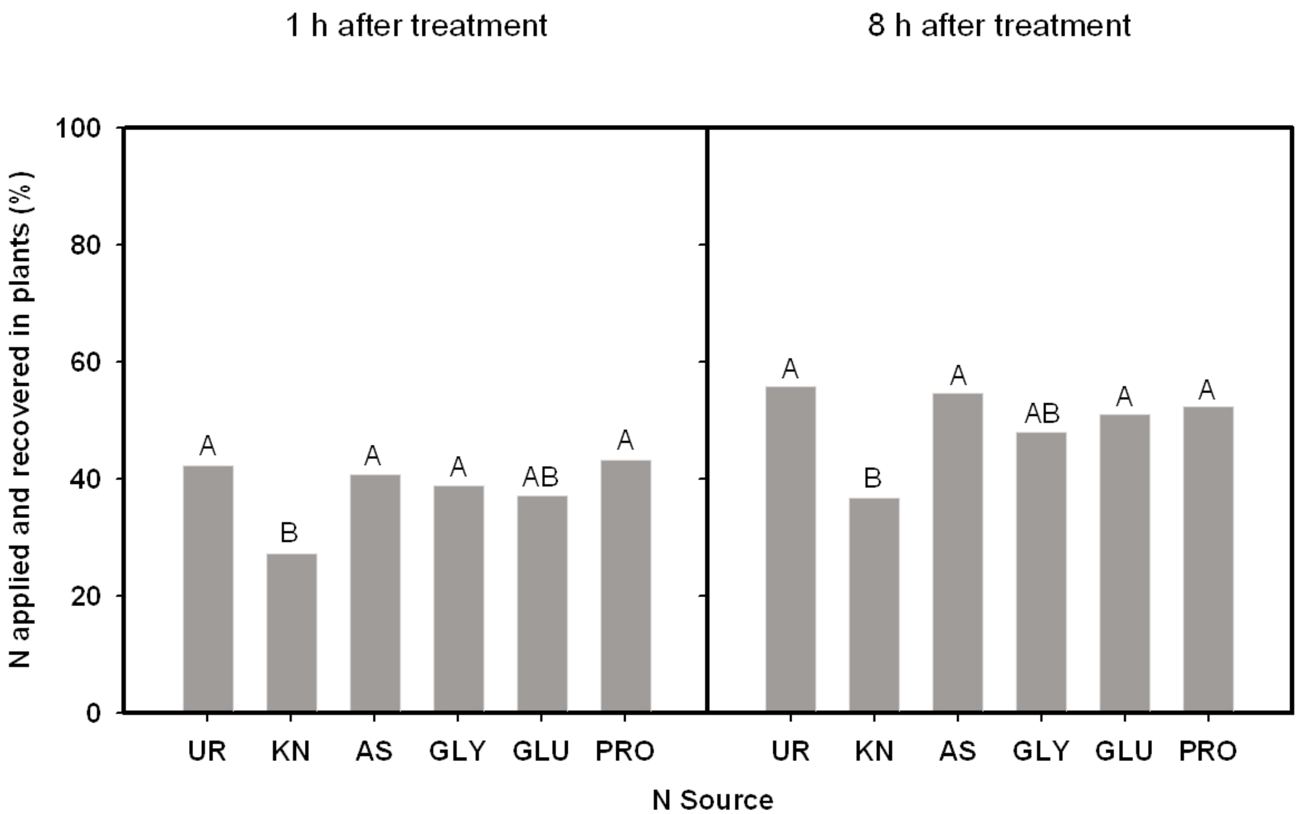

Fig. 1. Foliar uptake of N supplied by six different inorganic or organic N compounds (UR = urea, AS = $(NH_4)_2SO_4$, KN = KNO_3, GLY = glycine, GLU = glutamic acid, PRO = proline) sampled at 1 h (left) and 8 h (right) after treatment (Bars not sharing a letter are significantly different at $P < 0.05$).

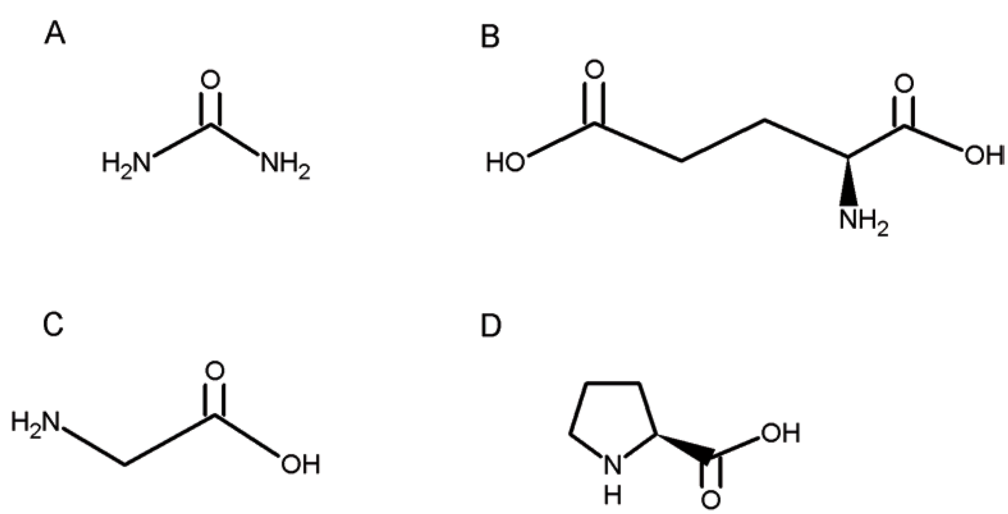

Fig. 2. Chemical structures of the synthetic and natural organic N compounds used in the study: (A) urea, (B) glutamic acid, (C) glycine, and (D) proline.