Direct Measurement of Foliar Absorbed Urea-Nitrogen Following Application to Putting Green Turfgrass Species

Photo by Josh Folkers

Foliar application of nutrients to putting green

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Summary. Foliar fertilization often comprises a significant portion of the total annual nitrogen (N) applied to putting greens. Despite the prevalent use of this N fertilization method, turfgrass scientific research efforts devoted to foliar absorption have been limited. Most glaringly, there have been no studies to date that document foliar uptake of N in a real-world, field setting. This study was initiated to evaluate the efficiency of this practice in the field and address the factors that may affect the foliar absorption process. A ^{15}N isotopic tracer field study was conducted to compare seasonal uptake of foliar-applied nitrogen by Penn A-1 creeping bentgrass and Tifeagle ultradwarf bermudagrass when managed for putting green utility. ^{15}N-labeled urea (46-0-0) was applied monthly, May through September, at rates of 0.10 lb N/1000 ft^2 and 0.25 lb N/1000 ft^2. Both species proved receptive to foliar uptake of urea-N, and absorption into plant tissues happened rapidly. A range of 24-57% of the fertilizer N applied was recovered in leaves/shoots at 1 h after treatment, while peak foliar absorption was generally observed at 4 h after treatment. Foliar uptake, when measured as a percentage of N applied, was significantly reduced at higher application rates on both species. Month of year significantly affected foliar absorption by creeping bentgrass. This was seen as a progressive reduction across the season in the percentage of N applied and recovered in creeping bentgrass plant tissue (May = 59%; September = 37%). However, no seasonal effect was observed on ultradwarf bermudagrass as percent foliar absorption remained fairly constant (45-50%) throughout the five months of this study.

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Foliar fertilization refers to the process of nutrient uptake through the foliage or other aerial plant parts. As a supplement to traditional root-feeding programs, foliar fertilization has been observed to be an increasingly common practice in today's golf course management. Lending credence to this perception, recent surveys of Arkansas golf course superintendents indicate that nearly all respondents use foliar fertilization on some area of their golf course and this method of nutrient application often comprises a major portion of annual nitrogen (N) inputs to putting greens (data not shown).

While there continues to be practical turfgrass research devoted to growth and color response from various foliar products, few studies have actually investigated foliar nutrient uptake dynamics or efficiency. The majority of these undertakings have come from a small group of researchers looking at N absorption into cool-season turfgrass leaves grown in controlled, moderate temperature environments (Wesely et al., 1985; Bowman and Paul, 1989; Bowman and Paul, 1990; Bowman and Paul, 1992). While these contributions have been significant, more research is needed to improve foliar nutritional strategies for golf course superintendents who wish to maximize plant uptake and reduce losses to the environment.

The development of a method to evaluate foliar uptake of N in the field would more closely resemble the seasonal environmental conditions that golf course superintendents face when using this practice. The importance of using real-world conditions when studying foliar fertilization is realized when considering previous agricultural research that shows that environmental factors and seasonal dynamics of leaf cuticle characteristics can influence the foliar absorption of N solutions (Oosterhuis et al., 1991; Bondada et al., 1997). Therefore, the aim of this project is to assess foliar uptake of N in the field, over successive months, during a two-year putting green research trial.

Materials and Methods

This field research study was conducted at the University of Arkansas Research and Extension Center in Fayetteville, Ark. Experimental areas of 'Penn A1' creeping bentgrass (*Agrostis stolonifera*) and 'Tifeagle' ultradwarf bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) were 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, four replicated plots were designated for each sampling date and each turfgrass species.

An isotopic tracer technique that allows for positive identification and direct measurement of fertilizer N in the plant tissue was used in this study. Applications of foliar urea-N were made once-monthly using urea (46-0-0 & 2.577 atom % ^{15}N), May through September 2007, to 2 by 4 ft plots with 6 inch borders. Treatments were repeated in the same months during 2008. 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. Application rates of 0.10 and 0.25 lb N/1000ft^2 were used and designated as a low and high rate, respectively. These correspond with foliar N application rates commonly used by golf course superintendents. For a 24 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, 4, 8, and 24 h after application to develop a time-course analysis of foliar N uptake.

Results and Discussion

Percentages of urea-N applied and recovered within plant tissue samples were affected by N rate and time allowed for spray droplets to remain on the surface of leaves prior to rinsing (i.e., sampling time). These significant ($P \leq 0.05$) main effects (N rate and time) were observed on both species, while the main effect of application month only affected foliar absorption of urea-N on creeping bentgrass. Statistical analysis revealed no higher-order interactions for either species. Therefore, further discussion will only focus on the main effects of N rate, month of year, and sampling time. Figures 1, 2, and 3 graphically represent these main effects and will be referred to throughout the discussion.

The use of the 0.25 lb N/1000 ft^2 (high) application rate compared to the 0.10 lb N/1000 ft^2 (low) rate resulted in significant reductions in foliar absorption. This trend was seen on both creeping bentgrass and ultradwarf bermudagrass putting green turf (Fig. 1). Averaged across all sampling times and application months on creeping bentgrass, the low N rate treatments measured 46% N uptake, while the high N rate was 40%. On ultradwarf bermudagrass, the percentage absorption differences were similarly affected by N rate (Fig. 1). We speculate that the nanometer-small hydrophilic pores within the leaf cuticle (Schonherr, 1976), where foliar absorption of sprayed solutions is deemed to take place, must have a limited capacity for entry of urea-N and/or the NH_4^+ ion. Based on this, turfgrass leaves may be more receptive to spray droplets of lower N concentration, which could explain our results. However, it should be noted that greater amounts of N were recovered within plant tissue when using the higher N rate; it was just a significantly smaller percentage of that which was applied.

As expected, the amount of time allowed between foliar urea-N application and subsequent plant sampling significantly affected foliar uptake (Fig. 2). Absorption of foliar urea-N through leaves on the putting green is a diffusion process that is governed by time and various other factors. General principles of diffusion dictate that the longer the solution is allowed to remain on leaf surfaces, the more possibility there is for increased foliar uptake. As such, the highest maximum mean percentage absorption of N (n = 4) achieved in our study was in the month of May on creeping bentgrass at 24 h after application (76%). However, looking at the curvilinear uptake graphs (Fig. 2), it should be noted that the greatest increase in percentage foliar absorption of N occurred between the sampling intervals of 0 and 1 h after application. This was consistent for both putting green turfgrass species and demonstrates the effectiveness of foliar urea-N applications in quickly supplying turf plants with this critical macronutrient.

From a statistical perspective, the effects of time on foliar absorption were somewhat different between the two species studied. Ultradwarf bermudagrass foliar uptake of N peaked at 4 h after application, while statistically significant portions of urea-N continued to diffuse into turfgrass leaves of creeping bentgrass up until the last sampling period of 24 h after treatment (Fig. 2). As a cool-season turfgrass species, creeping bentgrass undergoes heat- and water- deficit stress during the summer months in the transition zone. It has been well-documented in other crop species that as a means of coping with these stresses, plants respond by producing increased amounts and types of leaf surface waxes. Ultradwarf bermudagrass, being a warm-season turfgrass, would be expected to incur much less summer stress than creeping bentgrass. This could mean more plant acclimating leaf cuticle wax development on creeping bentgrass than on ultradwarf bermudagrass, leading to a more tortuous path for foliar N absorption and a slower time to peak absorption as seen here. From an agronomic perspective, though maximizing foliar uptake of urea-N on creeping bentgrass putting greens is a worthwhile goal of golf course superintendents, delaying necessary management practices (e.g., syringing greens, etc.) in an effort to obtain an extra 10% of N from a light rate foliar application is not likely to be practical or highly beneficial.

Seasonal effects (month of year for treatment event) on foliar absorption of urea-N applications were only seen on creeping bentgrass putting green turf and not on the ultradwarf bermudagrass. When expressed as a percentage of applied N recovered in plant tissue samples, there was a significant decrease as the season progressed. The May applications to creeping bentgrass putting greens (averaged across all sampling times and N rates) resulted in 59% absorption, while in July, August, and September these numbers lowered to 37-38% of that which was applied (Fig. 3). Foliar uptake of urea-N treatments on ultradwarf bermudagrass was not significantly affected from month to month and the average of percentage N absorbed across all sampling times and N rates was between 45-50%. The previously described theory of more leaf cuticle wax additions in response to magnified heat stress on creeping bentgrass vs. ultradwarf bermudagrass might also play a part in explaining the differences in seasonal uptake dynamics seen between the two species. It is currently believed that these alterations in leaf cuticle waxes also make the creeping bentgrass leaf surfaces more hydrophobic and, therefore, possibly less receptive to nutrient absorption. Continued laboratory investigations are underway to better understand this observed trend.

This study has been repeated and once data are compiled and analyzed, research-based recommendations to golf course superintendents for enhanced utilization of foliar nutrition on putting greens should be more concrete. However, based solely on first-year results there are a few take home points to convey. First, both creeping bentgrass and ultradwarf bermudagrass golf course greens are receptive to rapid foliar uptake of urea-N, and the efficiency of this practice is high when compared to the 33% global estimate of N-use efficiency for some agricultural crops (Raun and Johnson, 1999). However, foliar N fertilization of putting greens should generally be used as a supplement, and not a replacement, for traditional root-feeding methods. Secondly, in a practical sense, most of the urea-N applied to putting green turfgrass foliage is absorbed in the first 4 h after application. Lastly, foliar uptake efficiency by creeping bentgrass foliage was reduced during warmer months, suggesting a change in the composition of the leaf cuticle.

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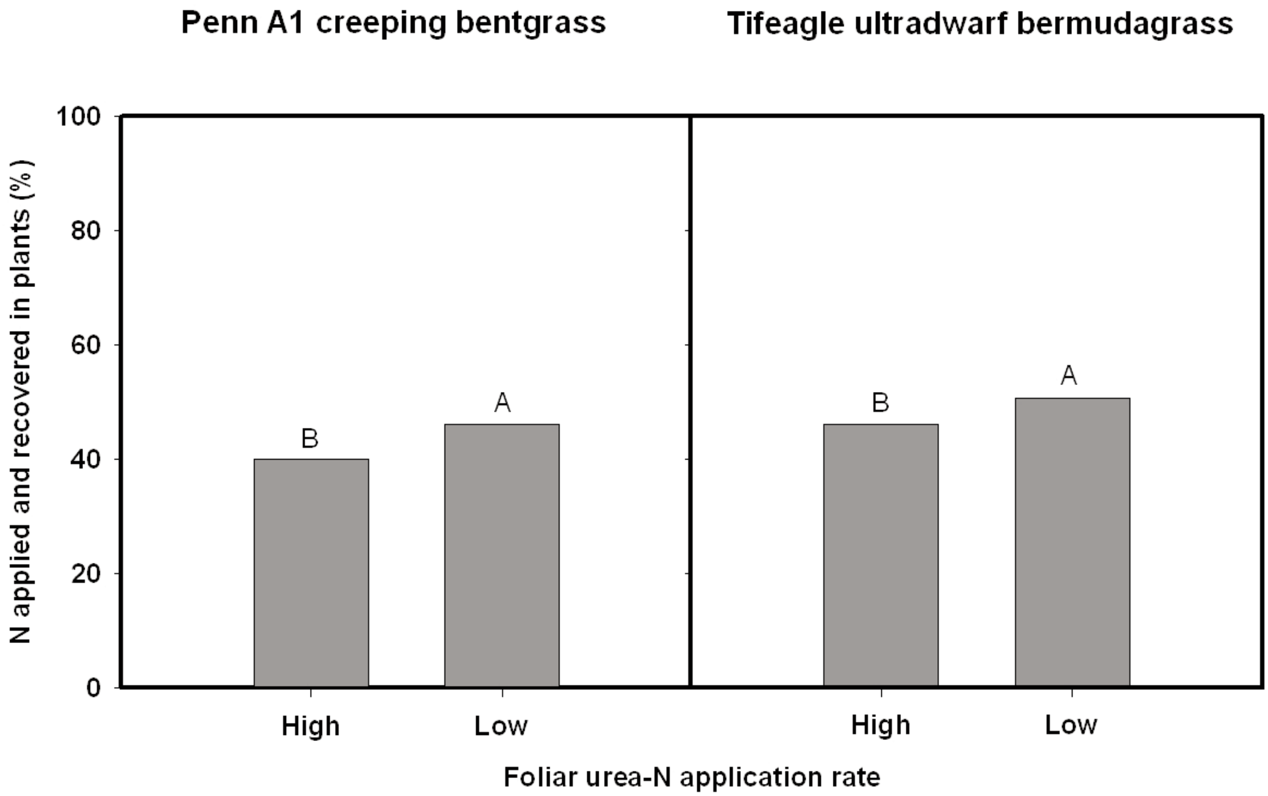

Fig. 1. Percentage of foliar urea-N absorption by Penn A1 creeping bentgrass (n = 159) and Tifeagle ultradwarf bermudagrass (n = 160) as affected by N rate. Bars with different letters indicate significant difference at $P \leq 0.05$.

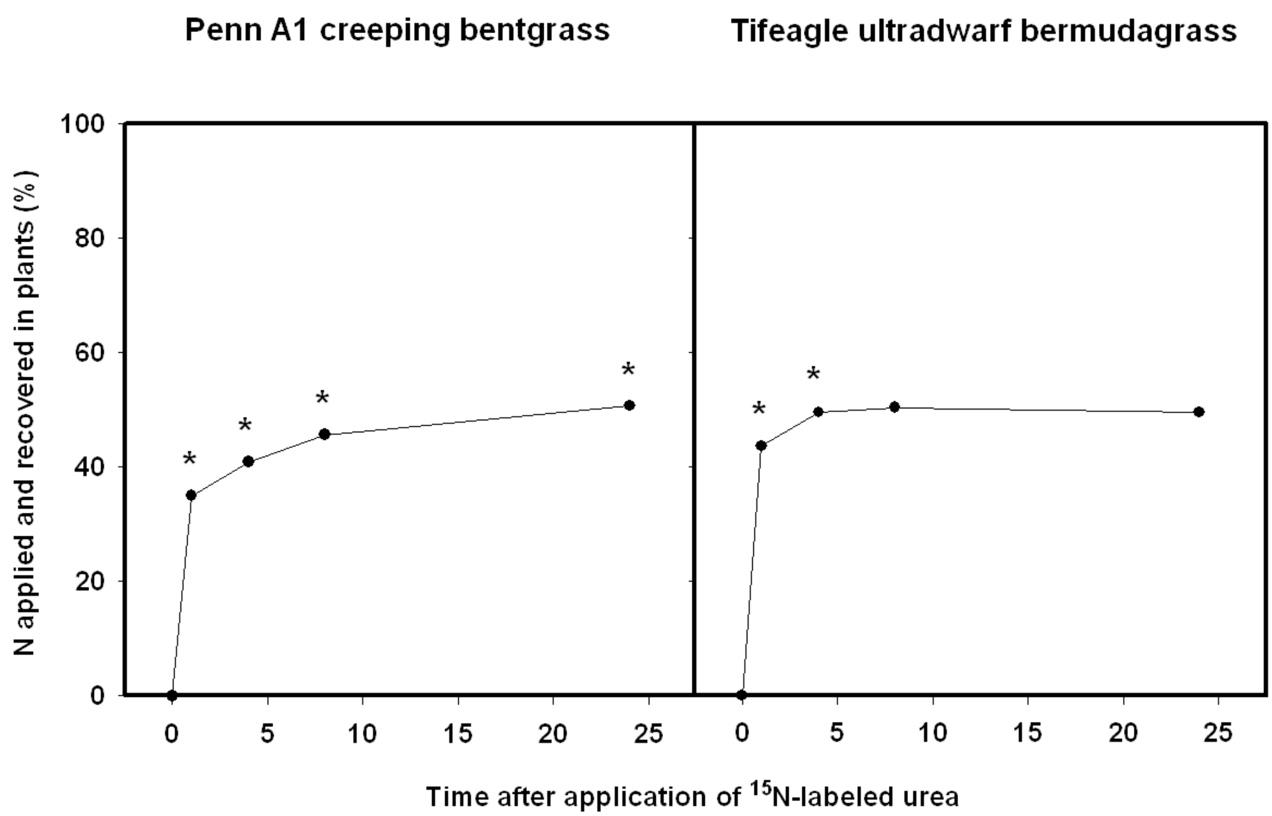

Fig. 2. Percentage of foliar urea-N absorption as affected by sequential sampling time intervals over a 24 h period after application (* denotes significant difference from previous sampling time at $P \leq 0.05$).

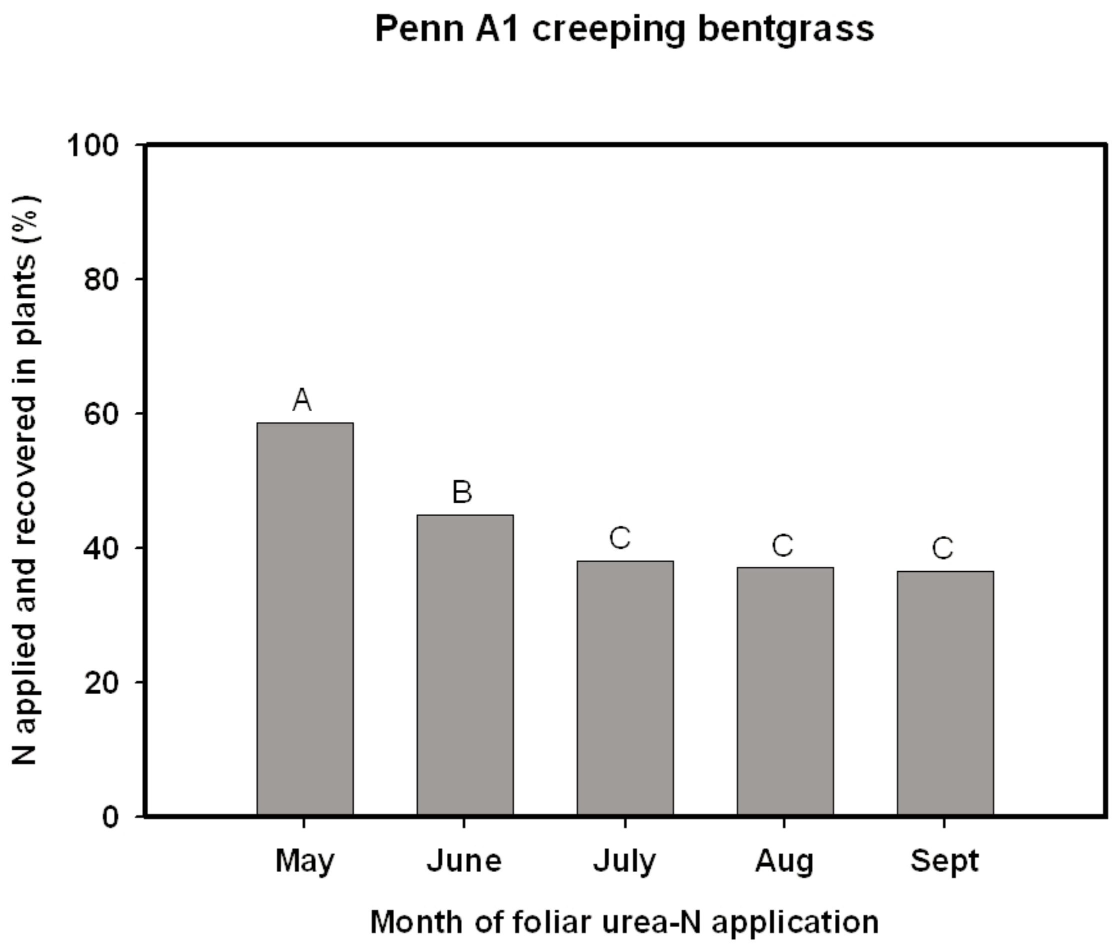

Fig. 3. Percentage of foliar urea-N absorption as affected by month of year in which application event took place. Bars with different letters indicate significant difference at $P \leq 0.05$ (n = 159).