

Nitrogen Rate and Season Influence Ammonia Volatilization Following Foliar Application of Urea to Putting Green Turf



NH₃ volatilization traps installed on plots

Photo by Chris Stiegler

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Summary. Foliar nitrogen (N) fertilization continues to gain popularity with golf course superintendents, especially in regard to putting green nutrition. However, little is currently known about the efficiency of this practice in the field, or the significance of the possible N-loss mechanisms associated with foliar applications. This project was conducted to document the extent of ammonia volatilization from turfgrasses managed as putting greens, following the applications of foliar N using urea (46-0-0), over a 24 h period. Two different foliar fertilizer rates (0.10 lb N/1000ft² and 0.25 lb N/1000ft²) were applied once monthly (May through September) to established putting greens of ‘Penn A-1’ creeping bent-

grass and ‘Tifeagle’ ultradwarf bermudagrass. This study was initiated in 2007 and repeated in 2008. Ammonia volatilization over a 24-h period was measured via boric acid trapping. Month of year and N rate both had a significant effect on the amount of N volatilized from the turfgrass canopy. The results from our field trial suggest that foliar urea-N applications to putting green turf can be made to actively growing plant tissue throughout the season without concern for substantial N loss via this pathway.

Abbreviations: NH₃ (ammonia), NH₄⁺ (ammonium), UAN (urea-ammonium nitrate), H₃BO₃ (boric acid), H₂SO₄ (sulfuric acid)

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Foliar fertilization is a common practice on today's intensively managed golf courses. A recent survey of golf course superintendents in Arkansas indicated that all respondents are using foliar fertilization on their putting greens and many superintendents apply over half of the nutrients to greens in this fashion (data not shown).

Urea and/or urea-ammonium nitrate (UAN) are common sources of nitrogen (N) included in foliar fertilizer products and when applied to the plant surface, there is risk of considerable N loss to the atmosphere as ammonia (NH_3) with these N sources. The presence of the urease enzyme, both on the leaf surface and within most plants (Witte et al., 2002), underlies NH_3 (ammonia) volatilization N-loss potential. Urease catalyzes the hydrolysis of urea into NH_3 and carbon dioxide. Under most conditions, the NH_3 then undergoes protonation ($\text{NH}_3 + \text{H}^+ \leftrightarrow \text{NH}_4^+$). While this is a highly important process for plants to assimilate urea-N into a plant-available form of ammonium (NH_4^+), NH_3 gas may also escape from the system (volatilize) during the process. Factors known to favor NH_3 volatilization include increased soil pH; increased surface temperature, moisture, or relative humidity; and wind speed (Joo, 1987; Knight et al., 2007).

Atmospheric losses of N as NH_3 gas, following the application of N fertilizers, have been well studied in agricultural research, while this same N-loss pathway from turfgrass stands has received considerably less research attention. Though several investigations into NH_3 volatilization from turfgrass stands have been reported, as shown in Turner and Hummel (1992), no such studies are known to be specific to N loss from the putting green turfgrass canopy following foliar-applied urea-N. Characteristics of foliar fertilization, such as soluble urea treatments made directly over the top of the plant canopy with low carrier rates, should negate the possibility of denitrification and/or leaching losses, as these are strictly soil/rootzone phenomena. Therefore, NH_3 volatilization should be the most important N-loss mechanism associated with typical foliar-N fertilization practices (McCarty,

2005). However, no studies to date have attempted to measure volatilization of NH_3 from golf course putting greens following foliar-N applications. Given this current lack of turfgrass scientific clarity, the objective of this study was to document the extent of N-loss from seasonal foliar applications of urea to a putting green turfgrass canopy.

Materials and Methods

This field research study was conducted at the University of Arkansas Research and Extension Center in Fayetteville, Arkansas. Experimental areas of 'Penn A1' creeping bentgrass (*Agrostis stolonifera*) and 'Tifeagle' ultradwarf bermudagrass (*Cynodon dactylon* x *Cynodon 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.

Applications of foliar urea-N were made once-monthly using urea (46-0-0), 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 gal/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/1000ft² 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.

Estimates of NH_3 volatilization were obtained through the use of an acid collection trap (4% H_3BO_3 solution with pH color indicator) housed in a small Petri dish, suspended within a bottomless 1-pint Mason jar (Fig. 1). Immediately after foliar-N treatments were applied, these apparatuses were directly inserted into the putting

green turf, completely enclosing a portion of the plot previously treated with urea fertilizer solution. These air-tight traps were modified in form and function but were designed after original specification details outlined by Mulvaney et al. (1997). The chambers were deployed for a period of 24 h after N application, then acid traps were collected, stabilized in-field, and transported to the laboratory for analysis. As described in Mulvaney et al. (1997), acidimetric titration with 0.01 M H₂SO₄ back to the original end point pH of the boric acid solution allowed for an indirect measurement of N loss via NH₃ volatilization.

Results and Discussion

Percentages of N applied and lost via NH₃ volatilization were influenced by N rate and month of urea-N application on both species. In addition, there were a few higher-order interactions between the two species. There were significant ($P < 0.05$) two-way interactions of month \times rate and year \times month on Tifeagle bermudagrass, while Penn A1 creeping bentgrass data exhibited a three-way interaction of year \times month \times rate. Figures 2 and 3 represent these respective interactions and discussion for each species will be focused on these graphs.

Ammonia volatilization from the Tifeagle bermudagrass putting green surface ranged from a pooled maximum of 10.4% (May 2008) to a pooled minimum value of 0.5% (June-low N rate). During all application months, the higher N application rate created volatile N losses that were numerically higher than those achieved with the lower N rate and in some cases this difference was significant (Fig. 2). This is not unexpected based on principles of enzyme kinetics. Increased urea (substrate) concentration on turfgrass leaves should result in increased urease enzyme activity, and a subsequently higher amount of NH₃/NH₄ (product) conversion coupled with an increased likelihood for volatile loss as NH₃.

In 2007, when foliar urea-N was applied to Penn A1 creeping bentgrass, NH₃ volatilization losses expressed as a percentage of applied N

ranged from a maximum of 1.4% (September-low N rate) to a minimum value of 0.2% (several monthly sampling dates and both N rates). On the last two experimental dates in August and September, the low foliar-N-rate plots had significantly more N loss via NH₃ volatilization than was observed in plots receiving a higher N rate (Fig. 3). This is dissimilar to what was seen on Tifeagle bermudagrass and is not easily explained based on the previously applied enzyme kinetic approach. It could simply be an aberration that arose due to the extremely low percentage of applied N generally lost from Penn A1 creeping bentgrass via NH₃ volatilization (Fig. 3). While, statistically, there was enough difference between the low and high rate during August and September to indicate significance, the numerical differences of 0.3 % and 0.6 % for these months, respectively, are not likely agronomically significant.

Acid-trap estimated volatilization of NH₃-N, resulting from 2008 monthly applications to Penn A1 creeping bentgrass, was also negligible. Comparatively, these numbers were even lower than were seen in 2007 with a maximum mean of 0.5% N loss (July-high rate) and a minimum of 0.0% (September-low rate). An N-rate effect was again observed in year 2 of the study with the May application date showing a significant difference between the high and low rate (Fig. 3). However, as discussed previously, finding statistical significance between two values less than 1% of the applied N holds no real practical significance to golf course superintendents.

Our data suggest that NH₃ volatilization from foliar urea-N application may not be a significant N-loss mechanism. Due to the design and use of our measurement devices (Fig. 1), much higher than normal ambient air/plant surface temperatures and a 100% relative humidity environment were inevitable within our NH₃ volatilization chambers. This should have created a worst-case scenario in regard to volatile losses of N. Despite this fact, the largest mean N loss observed in 2007 was 7.1% of the N applied, while in 2008 this number reached 13.7%. In both years, this abnormally high percent of N loss was

seen with the high N rate when applied to Tifeagle bermudagrass in May. It should be noted that in both instances, this particular experimental area had yet to achieve full green-up. This altered state of turfgrass growth and activity could have rendered the Tifeagle bermudagrass canopy less receptive to foliar uptake and resulted in greater than normal NH_3 volatilization. Indeed, subsequent observations on Tifeagle were vastly lower than this first month (Fig. 2), and this trend was consistent for both years.

Comparing our results to NH_3 volatilization loss previously reported using foliar applications of urea (Wesely, 1987), we observed much lower numbers with our methodology and experimental parameters. The substantially lower N rates used in this study, which are inherent to putting green foliar-fertilizer applications, could be the reason for this discrepancy. Another possible explanation for this could be that the high-density plant community created by the low mowing heights of putting green turfgrass culture makes for an ultrareceptive environment for foliar absorption of urea. This is a premise that we are currently investigating with a co-related foliar nutrient uptake study using ^{15}N -labeled urea on the same experimental areas. The ability of plant leaves to absorb the urea molecule shortly after foliar fertilization application (Wittwer et al., 1963) also has the capacity to limit NH_3 volatilization, since urea hydrolysis could take place inside the plant, rather than on the leaf surface.

Despite turfgrass literature reference to NH_3 -N loss via volatilization being a disadvantage when using foliar fertilization (McCarty, 2005), our two-year research study does not support this statement. Rather, the results from our field trial suggest that foliar urea-N applications to putting green turf can be made to actively growing plant tissue throughout the season without concern for substantial N-loss via this pathway.

Literature Cited

- Joo, Y.K. 1987. Effect of urease inhibitors and cationic materials on growth response and ammonia volatilization following fertilization of Kentucky bluegrass (*Poa pratensis* L.) with urea. Iowa State Univ., Ames, Iowa, Ph.D. Dissertation.
- Knight, E.C., E.A. Guertal, and C.W. Wood. 2007. Mowing and nitrogen source effects on ammonia volatilization from turfgrass. *Crop Sci.* 47:1628-1634.
- McCarty, L.B. 2005. (2nd ed.) Best golf course management practices. Pearson Prentice Hall Publishing Co., N.J.
- Mulvaney, R.L., S.A. Khan, W.B. Stevens, and C.S. Mulvaney. 1997. Improved diffusion methods for determination of inorganic nitrogen in soil extracts and water. *Biol. Ferti. Soils* 24:413-420.
- Turner, T.R., and N.W. Hummel, Jr. 1992. Nutritional Requirements and Fertilization. p. 385-439. In D.V. Waddington et al. (eds.) *Turfgrass-Agronomy Monograph no. 32.* ASA-CSSA-SSSA Publishers, Madison, Wis.
- Wesely, R.W., R.C. Shearman, E.J. Kinbacher, and S.R. Lowry. 1987. Ammonia volatilization from foliar-applied urea on field-grown Kentucky bluegrass. *HortScience* 22(6):1278-1280.
- Witte, C-P, S.A. Tiller, M.A. Taylor, and H.V. Davies. 2002. Leaf urea metabolism in potato. Urease activity profile and patterns of recovery and distribution of ^{15}N after foliar urea application in wild-type and urease-antisense transgenics. *Plant Physiol.* 128:1128-1136.
- 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, Wis.
- USGA. 1993. USGA recommendations for putting green construction. *USGA Green Section Record* 31(2):1-3.



Fig. 1. Apparatus used for in-field ammonia volatilization estimates.

Tifeagle bermudagrass

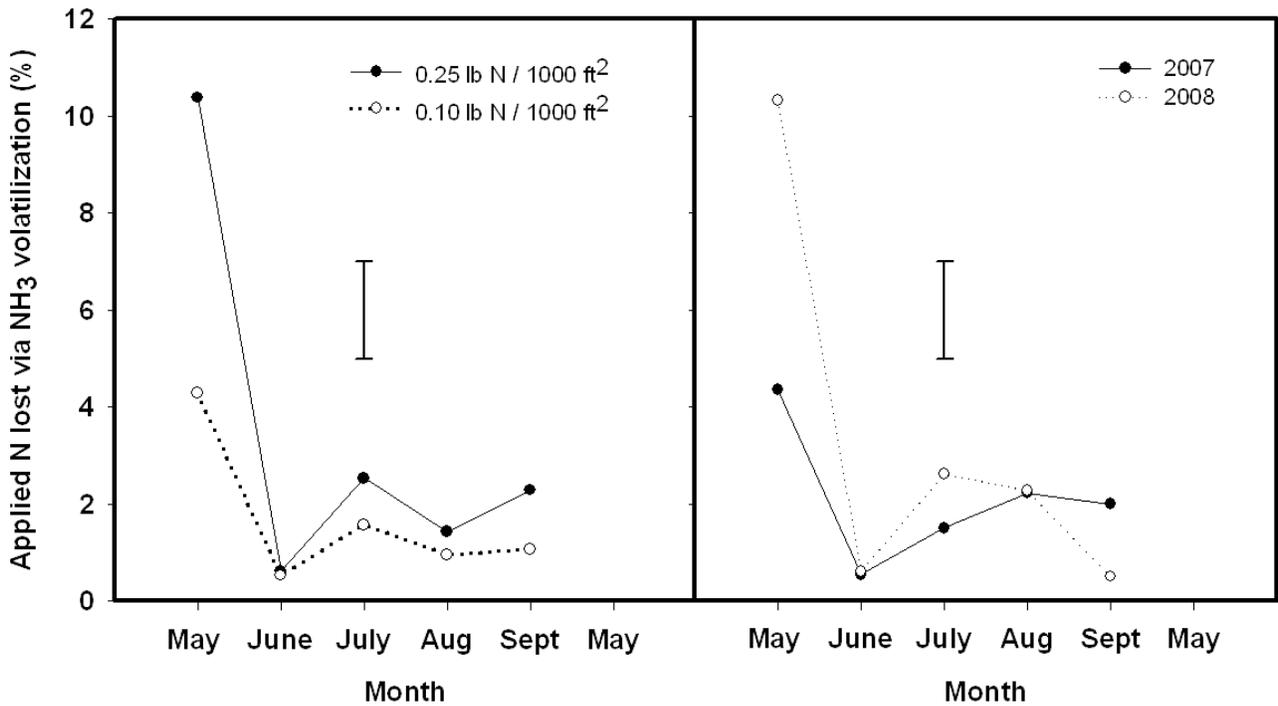


Fig. 2. Ammonia volatilization as affected by the following: (left) foliar urea application rate and sampling month; (right) year and sampling month. (LSD bar indicates significance at the 0.05 probability level).

Penn A1 creeping bentgrass

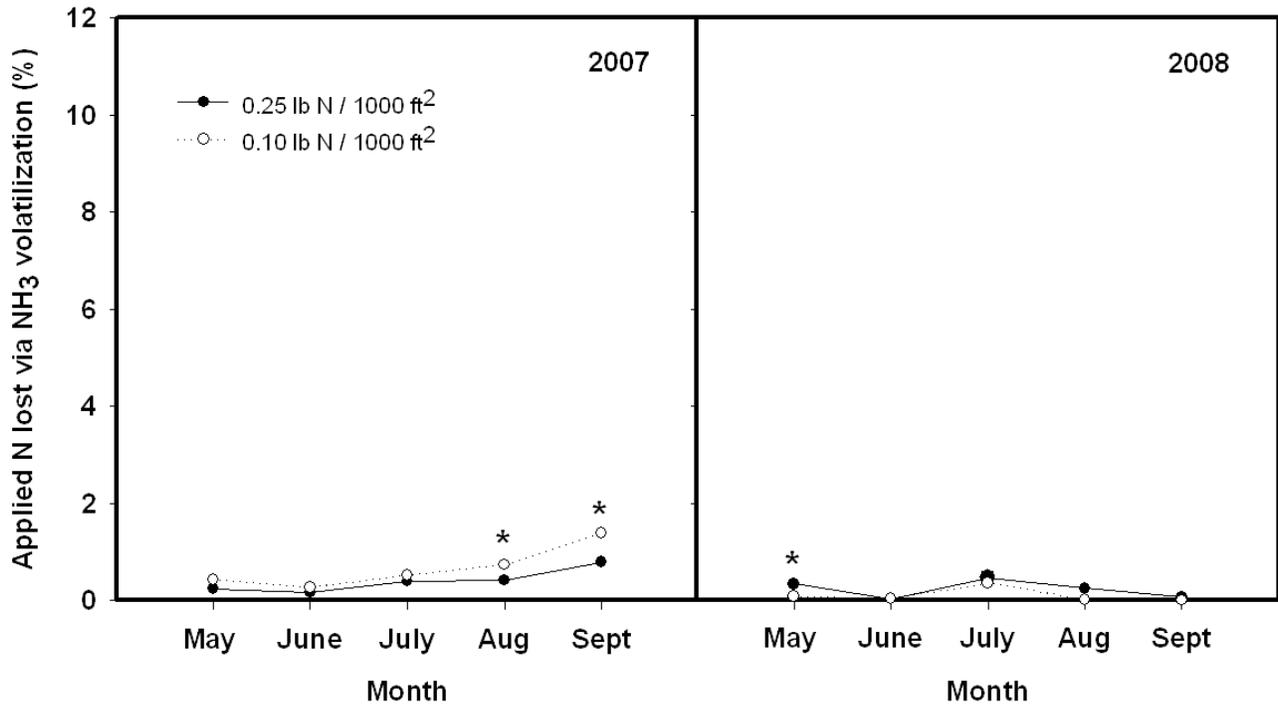


Fig. 3. Ammonia volatilization as affected by foliar urea application rate and sampling month during 2007 and 2008 (* denotes significance at the 0.05 probability level).