Indirect Measurement of Ammonia Volatilization Following Foliar Applications of Urea on a Cool- and Warm-season Putting Green Turfgrass Species

Chris Stiegler[1], Mike Richardson[1], John McCalla[1], Josh Landreth[1], and Trent Roberts[2]

Additional index words: creeping bentgrass, ultradwarf bermudagrass, nitrogen

Stiegler, C., M. Richardson, J. McCalla, J. Landreth and T. Roberts. 2008. Indirect measurement of ammonia volatilization following foliar applications of urea on a cool- and warm-season putting green turfgrass species. Arkansas Turfgrass Report 2007, Ark. Ag. Exp. Stn. Res. Ser. 557:80-84.

Photo by Mike Richardson

Volatilization studies conducted on creeping bentgrass

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 and 0.25 lb N / 1000ft^2) were applied once monthly (May through September) to 'Penn A-1' creeping bentgrass and 'Tifeagle' ultradwarf bermudagrass established putting greens. 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. At each sampling date and on both species, measurement of ammonia volatilization was consistently small with a maximum observed loss of 7%.

1 Department of Horticulture, University of Arkansas, Fayetteville, Ark. 72701
2 Department of Crop, Soil, and Environmental Sciences, University of Arkansas, Fayetteville, Ark. 72701

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 surface, and within most plants (Witte et al., 2002), underlies ammonia volatilization N-loss potential. Urease catalyzes the hydrolysis of urea into NH_3 and carbon dioxide. Under most conditions, the NH3 then undergoes protonation ($NH_3 + H^+ \longleftrightarrow NH_4^+$). 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 (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 phenomena. Therefore, ammonia volatilization should be the most important N-loss mechanism associated with typical N foliar fertilizer 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. 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 creeping bentgrass (*Agrostis stolonifera* cv. Penn A1) and ultradwarf bermudagrass (*Cynodon dactylon* x *C. transvaalensis* cv. Tifeagle) were established on a sand-based putting green (USGA, 1993) and were 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 N were made once-monthly using urea (46-0-0), May 2007 through September 2007, to 2 by 4 ft plots with 6 inch borders. Foliar N was applied in 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 in order to produce a fine atomized spray pattern for even, thorough plot coverage facilitating foliar uptake. Rates of 0.10 and 0.25 lb N / 1000 ft^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-hr period after treatment, plots received no irrigation or rainfall in order to limit all N absorption to the foliar uptake pathway.

Estimates of ammonia 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. Acidimetric titration with 0.01 M H_2SO_4 back to the original end point pH of the boric acid solution allowed for an indirect measurement of N loss via NH_3 volatilization.

Results and Discussion

Percentages of N applied and lost via NH_3 volatilization from Tifeagle bermudagrass putting green surface ranged from a maximum of 7.1% (May-high N rate) to a minimum value of 0.55% (June and July-low N rate) (Fig. 2). On three of the five monthly sampling dates, the higher N application rate created volatile N losses that were significantly higher than those achieved with the lower N rate (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 NH_3/NH_4 (product) conversion coupled with an increased likelihood for volatile loss as NH_3.

When foliar urea-N was applied to Penn A1 creeping bentgrass, NH_3 volatilization losses ranged from a maximum of 1.4% (September-low N rate) to a minimum value of 0.2% with both N rates at several monthly sampling dates. On the last two experimental dates (August and September), the low foliar N-rate plots had significantly more N loss via NH_3 volatilization than was observed in plots receiving a higher N rate (Fig. 2). 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 A-1 creeping bentgrass via NH_3 volatilization (Fig. 2). 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, is not likely to have an agronomic significance.

These preliminary data suggest that NH_3 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 NH_3 volatilization chambers. This should have created a worst-case scenario in regard to volatile losses of N. Despite this fact, the largest loss observed in 2007 monthly applications was 7% of applied N volatilized from Tifeagle bermudagrass at the high rate on the May application date. It should be noted that a hard freeze in early April 2007 served as a physiological set back for the Tifeagle putting green species and therefore, at the time of our May applications, 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 lower than this first month.

Comparing our results to previously reported NH_3 volatilization losses in turfgrass scientific literature, in general, we observed much lower numbers with our methodology and experimental parameters. The substantially lower N rates used in this study, which are inherent to 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 ultra-receptive environment for foliar absorption of urea. This is a premise that we are currently investigating with a co-related foliar nutrient uptake study using 15N 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.

No conclusive statements regarding volatile NH_3-N losses and foliar urea-N applications to putting green turf can be made until summer 2008 data collection is complete. However, 2007 data suggest that this supplemental nutritional strategy can be employed throughout the growing season by golf course superintendents 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.

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 15N 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.

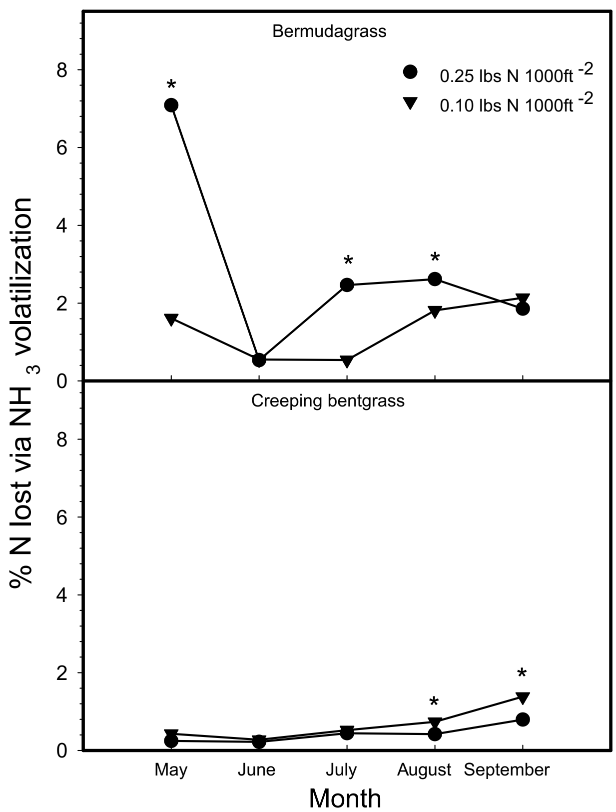

Fig. 2. Ammonia volatilization as affected by foliar urea application rate and sampling month. (* denotes significance at the 0.05 probability level)