

# Ammonia Volatilization Following Foliar Application of Various Liquid and Granular-soluble Nitrogen Sources to Putting Green Turf

Chris Stiegler<sup>1</sup>, Mike Richardson<sup>1</sup>, John McCalla<sup>1</sup>, Josh Summerford<sup>1</sup>, and Trent Roberts<sup>2</sup>

**Additional index words:** creeping bentgrass, fertilization, boric acid trap

Stiegler, C., M. Richardson, J. McCalla, J. Summerford, and T. Roberts. 2010. Ammonia volatilization following foliar application of various liquid and granular-soluble nitrogen sources to putting green turf. *Arkansas Turfgrass Report 2009*, Ark. Ag. Exp. Stn. Res. Ser. 579:82-86.



Photo by Josh Landreth

Partial view of the experimental area after foliar N treatments were spray-applied and ammonia volatilization chambers were installed within each plot.

**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 (NH<sub>3</sub>) volatilization from a creeping bentgrass putting green following the application of various foliar N sources commonly used by local golf course superintendents. Regardless of label rate indicated on each liquid or soluble foliar fertilizer source, each product was mixed with deionized water and applied at a common rate of 0.25 lb N/1000ft<sup>2</sup>. Applications were made once per year in late August/early September of

2007 and 2008 to a ‘Penn G-2’ creeping bentgrass putting green. Ammonia volatilization over a 24 h period was measured via boric acid trapping. Percentages of N applied and lost via NH<sub>3</sub> volatilization, when averaged across years, were less than one percent for each source used in this study. Attempts were made to utilize environmental conditions that would exacerbate NH<sub>3</sub> volatilization potential. Therefore, the results from our field trial suggest that, regardless of fertilizer source or chemical form, foliar N application (typical N rates) to putting green turf can be made without concern for substantial N loss via volatilization.

**Abbreviations:** N, nitrogen; NH<sub>3</sub>, ammonia; NH<sub>4</sub><sup>+</sup>, ammonium; UAN, urea-ammonium nitrate; H<sub>3</sub>BO<sub>3</sub>, boric acid; H<sub>2</sub>SO<sub>4</sub>, sulfuric acid

<sup>1</sup> University of Arkansas, Department of Horticulture, Fayetteville, Ark. 72701

<sup>2</sup> University of Arkansas, Department of Crop, Soil, and Environmental Sciences, 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 ( $\text{NH}_3$ ) with these N sources. The presence of the urease enzyme both on the leaf surface, and within most plants (Witte et al., 2002), underlies ammonia volatilization N-loss potential. Urease catalyzes the hydrolysis of urea into  $\text{NH}_3$  and carbon dioxide. Under most conditions, the  $\text{NH}_3$  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 ( $\text{NH}_4^+$ ),  $\text{NH}_3$  gas may also escape from the system (volatilize) during the process. Factors known to favor  $\text{NH}_3$  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  $\text{NH}_3$  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 comparably less research attention. Some investigations into  $\text{NH}_3$  volatilization from turfgrass stands have been reported, as shown in Turner and Hummel (1992); however, no such studies are known to be specific to N loss from the putting green turfgrass canopy following the application of different foliar-applied N sources. Characteristics inherent to foliar fertilization, such as liquid/soluble 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 or rootzone 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  $\text{NH}_3$  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 foliar applications of various products obtained from local golf course superintendents who use them for putting green nutrition.

## Materials and Methods

This field research study was conducted at the University of Arkansas Agricultural Research and Extension Center in Fayetteville, Ark. An experimental area of 'Penn G2' creeping bentgrass (*Agrostis stolonifera*) 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 treatment and application date.

Nine different N sources were collected from golf course superintendents in Arkansas who had previously indicated use of these selected products as foliar treatments on their golf course putting greens. These fertilizer products, along with a control (deionized water), made up our foliar treatments for 2007 and 2008 application dates (Table 1). Applications were made on 29 August 2007 (88 °F max air temperature) and repeated the next year on 7 September 2008 (85 °F max air temperature) to 2 ft by 4 ft plots with 6 inch borders. Foliar N application timing was selected during late August or early September when air temperatures would be expected to increase ammonia volatilization potential. Admittedly, air temperatures were higher at other times during each year, but timing and scheduling application events to coincide with the warmest days proved difficult. Foliar N was applied in 58 gallons/acre with the aid of a spray shield and a single nozzle  $\text{CO}_2$ -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. For a 24 h period after treatment, plots received no irrigation or rainfall.

Regardless of the label rate indicated on the

various liquid or soluble foliar fertilizer sources, products were mixed to achieve a common rate of 0.25 lb N/1000 ft<sup>2</sup> for each N source treatment. This application rate was selected because it was considered to be a foliar N rate on the higher end of what would commonly be used by golf course superintendents. Based on enzyme kinetics, an increased urea (substrate) concentration on turfgrass leaves should result in increased urease enzyme activity, and a subsequently higher amount of NH<sub>3</sub>/NH<sub>4</sub> (product) conversion coupled with an increased likelihood for volatile loss as NH<sub>3</sub>.

Estimates of ammonia volatilization were obtained through the use of an acid collection trap (4% H<sub>3</sub>BO<sub>3</sub> 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 H<sub>2</sub>SO<sub>4</sub> back to the original end point pH of the boric acid solution, allowed for an indirect measurement of N loss via NH<sub>3</sub> volatilization.

## Results and Discussion

Due to a lack of homogeneity between the 2007 and 2008 data, statistical analysis was performed separately for each year. Percentages of N applied and lost via NH<sub>3</sub> volatilization were significantly ( $P \leq 0.05$ ) affected by foliar N source in 2007, but this factor was not statistically significant in 2008. Numerical values of N lost via NH<sub>3</sub> volatilization after application of the various fertilizer sources were very small and ranged from 0.0% to 1.4% (Table 1). Therefore, even though there were some statistical differences among the foliar N sources based on computational analysis of 2007 data, it is questionable whether these dif-

ferences are meaningful and even worth noting for further discussion.

Overall, our data suggest that NH<sub>3</sub> volatilization from foliar N application may not be a significant N loss mechanism (Table 1). 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<sub>3</sub> volatilization chambers. This should have created a worst-case scenario in regard to volatile losses of N. Despite this fact, along with pre-selecting dates of application to correspond with higher ambient temperatures, the largest N loss observed within any single acid trap sample among our treatments was only 1.4% of the N applied.

Comparing our results to NH<sub>3</sub> volatilization loss previously reported using foliar applications of urea (Wesely et al., 1987), we observed much lower numbers with our methodology and experimental parameters. The lower N rates used in this study, which are typical of putting green foliar fertilizer applications, could be the reason for this discrepancy. Wesely et al. (1987) applied foliar rates of 0.35 lb N/1000 ft<sup>2</sup> and 0.7 lb N/1000 ft<sup>2</sup> to higher cut Kentucky bluegrass and reported volatile losses in the range of 35%. 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 a very receptive environment for foliar absorption of N compounds. Rapid foliar uptake of N, which has been previously reported in our other foliar fertilizer studies (Stiegler et al., 2009b; Stiegler et al., 2009c), also has the capacity to limit NH<sub>3</sub> volatilization as a result of N transformations taking place inside the plant, rather than on the leaf surface.

Despite turfgrass literature reference to NH<sub>3</sub>-N loss via volatilization being a disadvantage when using foliar fertilization (McCarty, 2005), this study along with another two-year investigation using only urea (Stiegler et al., 2009a) do not support these statements. Since this study isolated late summer month applications in both years, when air temperature maximums were close to 90 °F and these are conditions known to exacerbate

NH<sub>3</sub> volatilization, data obtained were believed to be a worst-case scenario to gauge the extent of volatilization potential. Therefore, the results from our field trials suggest that foliar applications (using common N rates  $\leq 0.25$  lb N/1000 ft<sup>2</sup>) to putting green turf, regardless of N source or chemical form, can be made to actively growing plant tissue throughout the season without concern for substantial N loss via volatilization.

It should be noted, however, that a post-experiment analytical check of our field apparatus, using <sup>15</sup>NH<sub>3</sub> alkali liberation from <sup>15</sup>(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> solutions of known N mass, revealed that the NH<sub>3</sub> trapping efficiency of boric acid traps housed within our chambers was less than quantitative (data not shown). Interestingly, the creeping bentgrass tissue enclosed within the volatilization chambers was as comparable in sink strength for NH<sub>3</sub> gas as the boric acid traps. In other words, due to the potential for turfgrass leaf tissue to directly absorb some of the NH<sub>3</sub> floating off the plant canopy through stomata, adjusting our data by increasing two to three-fold may be warranted. Due to the very low initial percentages of applied N lost via volatilization (Table 1), even after such manipulation, we are confident that our studies still allude to a minimized potential for volatile loss following application of various foliar-applied N forms to creeping bentgrass putting greens.

#### 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.
- Stiegler, C., M. Richardson, J. McCalla, J. Summerford, and T. Roberts. 2009a. Nitrogen rate and season influence ammonia volatilization following foliar application of urea to putting green turf. *Arkansas Turfgrass Report 2008*, Ark. Ag. Exp. Stn. Res. Ser. 568:110-115.
- Stiegler, C., M. Richardson, and J. McCalla. 2009b. 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.
- Stiegler, C., M. Richardson, J. McCalla, and J. Summerford. 2009c. Direct measurement of foliar absorbed urea-nitrogen following application to putting green turfgrass species. *Arkansas Turfgrass Report 2008*, Ark. Ag. Exp. Stn. Res. Ser. 568:121-126.
- 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-CS-SA-SSSA Publishers, Madison, Wis.
- USGA. 1993. USGA recommendations for putting green construction. *USGA Green Section Record* 31(2):1-3.
- 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 <sup>15</sup>N after foliar urea application in wild-type and urease-antisense transgenics. *Plant Physiol.* 128:1128-1136.

**Table 1. Percentage of N applied and lost via ammonia volatilization, during the initial 24 hours after fertilization, as affected by foliar N source during 2007 and 2008 experimental dates.**

Foliar N source	29 August 2007	7 September 2008
	-----%-----	
Urea (46-0-0)	1.41	0.18
Anderson's (28-5-18)	1.10	0.08
PBI Gordon Ferrmec (15-0-0)	1.05	0.00
Ammonium sulfate (21-0-0)	0.99	0.00
Coron (10-0-11)	0.96	0.19
Floratine Carbon Power (24-0-0)	0.92	0.35
Plantex (12-0-44)	0.89	0.00
Emerald Isle Seaquestial (7-0-1)	0.86	0.39
Control (DI H <sub>2</sub> O)	0.86	0.00
Earthworks Calvantage (6-0-0)	0.75	0.43
LSD <sub>0.05</sub> <sup>z</sup>	0.16	NS

<sup>z</sup> Least significant difference at 0.05 probability level can be used to compare means within an experimental date; ns = not significant.



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