UREA AND AMMONIA VOLATILIZATION IN DRYLAND GRASS SEED SYSTEMS[1]

Richard Koenig, Christopher Proctor, William Johnston, and Charles Golob
Department of Crop and Soil Sciences
Washington State University, Pullman

ABSTRACT

The purpose of this study was to evaluate the influence of grass seed production conditions and management practices on NH_3 volatilization, Kentucky bluegrass seed yields and N recovery from urea. Laboratory incubations suggest the potential for NH_3 volatilization is greater from stands in which post-harvest residue is baled and removed than from stands in which residue is burned. Both burned and unburned stands have a surface pH > 7.9, although pH declined with time in the burned system. While the burned stand had higher surface temperatures on sunny days, burning also lowered urease enzyme activity. Preliminary results from the field were similar to those in the lab, indicating higher rates of NH_3 volatilization from a bluegrass stand that was not burned. Rates of NH_3 volatilization were also higher with urea and fluid urea ammonium nitrate (UAN) applied in mid-November compared to early October, presumably due to a higher soil moisture content in November. Kentucky bluegrass seed yield and N recovery will be measured in 2007.

INTRODUCTION

Beginning in 2005, fertilizer distributors in the Pacific Northwest (PNW) stopped carrying dry ammonium nitrate (34-0-0). For grass seed growers in E. Washington and N. Idaho previously accustomed to making broadcast applications of 34-0-0, urea (46-0-0) and fluid urea ammonium nitrate (UAN, 28 or 32-0-0) are now the main alternatives. Growers are understandably concerned about the potential for NH_3 volatilization from dry and fluid urea fertilizers. Research has shown that, under ideal conditions, volatile NH_3 losses from urea can exceed 50% of the total N applied (Terman, 1979). Conversely, with appropriate management NH_3 volatilization can be minimized (Kissel, 1993). Unfortunately, many of the conditions that promote NH_3 volatilization are the same as those in which N is managed in grass seed systems. These include broadcast applications in high residue conditions, high soil and air temperatures, and little or no precipitation following application. Ammonia volatilization from urea broadcast on grass seed stands after burning (i.e., some fields in Idaho) may also be higher than on fields where residue is baled and removed, since ash is an alkaline material and high pH can enhance volatilization from urea-based N sources (Kissel, 1993).

Management is the key to reducing NH_3 volatilization. Delayed fall application, use of alternative sources such as fluid UAN instead of dry urea, and/or placement of fluids in a band on or below the surface may reduce NH_3 volatilization. However, delayed fall application may reduce the potential for fall regrowth, which is critical to establishing seed yield potential, and subsurface placement may cause excessive stand disturbance. The purpose of this study was to

evaluate the influence of grass seed production conditions and management practices on NH_3 volatilization, grass seed yield and N recovery from urea.

METHODS

A laboratory procedure was used to evaluate NH_3 volatilization potential under simulated grass seed production conditions. A bulk sample of silt loam soil (pH = 5.7) was collected from the field and homogenized. Five-hundred g of soil at an initial gravimetric moisture content of 12% was placed in glass dishes 8-inches in diameter and 6-inches tall. Kentucky bluegrass residue was applied to the surface of a subset of dishes at the rate of 2 tons/acre. Bluegrass residue was added at the same rate to an additional subset of treatments and then burned. Various fertilizer sources (nothing, urea, ammonium nitrate, etc.) were broadcast at the equivalent rate of 100 lb N/ac to the soil, residue and burned residue treatments in a series of experiments. Moisture and temperature were also varied in additional studies to ascertain the influence of soil and environmental conditions on NH_3 volatilization. Each treatment was replicated three times. A glass vial containing 10 ml boric acid solution at pH 5.2 was placed in each dish. The boric acid serves as a trap for volatilized NH_3 (Koenig et al., 2005). Dishes were covered with plastic and incubated at constant temperature. Traps were replaced at 2 to 3-day intervals for 7 to 12 days. Traps were titrated with standardized hydrochloric acid to a pH 5.0 end point determined with a methyl red indicator. The amount of NH_3 captured in the trap was determined by the volume and normality of acid used to titrate the trap to the end point, minus that required to titrate unexposed vials. The pH of soil, residue and ash was also measured with a microelectrode. Urease enzyme activity was determined in soil, residue and ashed residue as described by Torello and Wehner (1983).

A preliminary N source field study was conducted at one eastern Washington location in 2005 - 2006. Nitrogen was applied at a rate of 100 lb N/ac as ammonium nitrate, urea or fluid UAN to an established stand of Kentucky bluegrass on October 15, 2005. Dry urea and ammonium nitrate was broadcast on the surface and fluid UAN was dribbled in bands on the surface spaced 7½ inches apart. In addition, dry urea and fluid UAN were placed in a band 1½ to 2 inches below the surface using a double disk no-till drill with 7½-inch spacing. An unfertilized control was also included. Plots were 7 ft wide by 30 ft long. Grass seed yield was determined by harvesting an area from the center of each plot, threshing the plants and cleaning the seed. Whole plant subsamples were also collected from areas of known dimension, dried and weighed to determine above-ground dry matter yield, and then ground and analyzed for tissue N concentration to determine total N uptake and apparent N recovery.

Additional field studies were initiated in fall 2006 at three locations in eastern Washington and northern Idaho. At two locations residue had been baled and removed. Residue at the third location was burned after harvest. Nitrogen was applied at rates of 100 lb N/ac at two sites and 150 lb N/ac at one site based on grower practice. Nitrogen sources including urea, ammonium nitrate, and a controlled release form of N (ESN[®]) were broadcast on the surface, and fluid UAN was applied in surface in bands spaced 7½ inches apart. In addition, dry urea and fluid UAN were placed in a band 1½ to 2 inches below the sod surface using a double disk no-till drill with 7½-inch spacing. An unfertilized control was also included. Applications were made on two dates (October 5 and November 15). Gravimetric soil moisture and surface pH (using a microelectrode) were measured in intact cores collected prior to each application. Soil and air temperatures were measured for a period of 7 to 12 days after each fertilization event. Ammonia volatilization was measured in unfertilized control, broadcast urea and ammonium nitrate, and

the surface banded fluid UAN treatments for 7 to 12 days after each application. Volatilization was measured using an adaptation of the laboratory method in which a boric acid vial was placed on the soil surface immediately after application and a glass jar placed over the vial to contain volatilized NH_3. Boric acid vials were replaced every 2 to 3 days, returned to the lab, and titrated as described above in the laboratory procedure.

RESULTS AND DISCUSSION

In the lab, rates of NH_3 volatilization were low from unfertilized control and ammonium nitrate treatments (Figure 1). Volatilization rates were significantly higher at 2 to 5 and 5 to 7-d intervals after urea application to soil covered with bluegrass residue compared to a bare soil surface or soil with residue that had been burned. The rate of NH_3 volatilization declined by the 7 to 12-d interval in the residue treatment and was similar to rates in bare soil alone or soil with burned residue. We attribute the decline in the residue treatment to microbial immobilization of N reducing the amount of NH_3 subject to volatilization. Fungal mycelia growth was clearly evident in the residue treatment after 7 d of incubation.
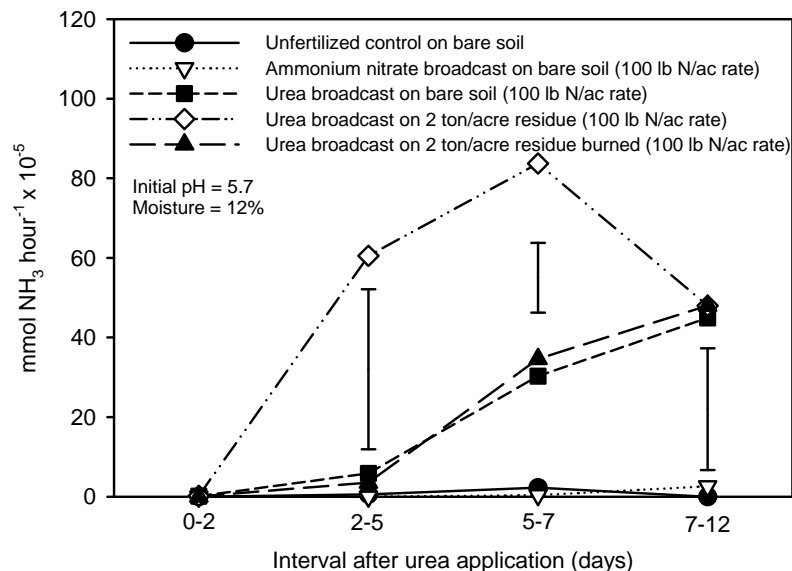

Figure 1. Ammonia volatilized and captured in boric acid solution from various N source and surface bluegrass residue treatments incubated in the laboratory at 70° F. The vertical bars represent least significant difference values at the 10% level ($LSD_{0.10}$).

Higher rates of NH_3 volatilization have been found to occur with broadcast urea in reduced tillage or perennial grass systems due to high urease enzyme activity in plant residues (Torello and Wehner, 1983; Kissel, 1993). The *in situ* pH of soil, residue and burned residue measured with a microelectrode averaged 5.65, 8.57 and 9.54, respectively. This suggests that another factor leading to high NH_3 volatilization rates from residue-covered surfaces may be the inherently high pH of the residue. Our original hypothesis was that burned bluegrass residue would also lead to higher rates of NH_3 volatilization than bare soil or soil covered with residue due to the high pH of the ash layer. This was not the case. However, urease assays revealed net enzyme activities of 6.4, 14.8 and 0.9 µg NH_4 g^{-1} hr^{-1} in the soil, residue and burned residue

treatments, respectively. This suggests that, while burning residue does increase pH at the surface, the significant reduction in enzyme activity may lead to lower NH_3 volatilization potentials than with an unburned residue surface.

In the field there was no significant difference in clean seed yield between an unfertilized control and fertilized treatments in 2006 (Figure 2), suggesting that the site chosen for this preliminary study was not N limited. This was further supported by apparent N recovery values (% of applied N recovered in treatments compared to control) of <3% across treatments. On average, however, subsurface banding of dry urea or fluid urea ammonium nitrate, or surface banding of fluid urea ammonium nitrate, did result in 19% lower seed yield than broadcasting dry ammonium nitrate or urea. Stand disturbance may explain the lower yields observed with the subsurface band placement. The reason for lower yields with the surface band UAN treatment is not clear although there was some evidence of leaf tissue burning with fluid UAN applications.
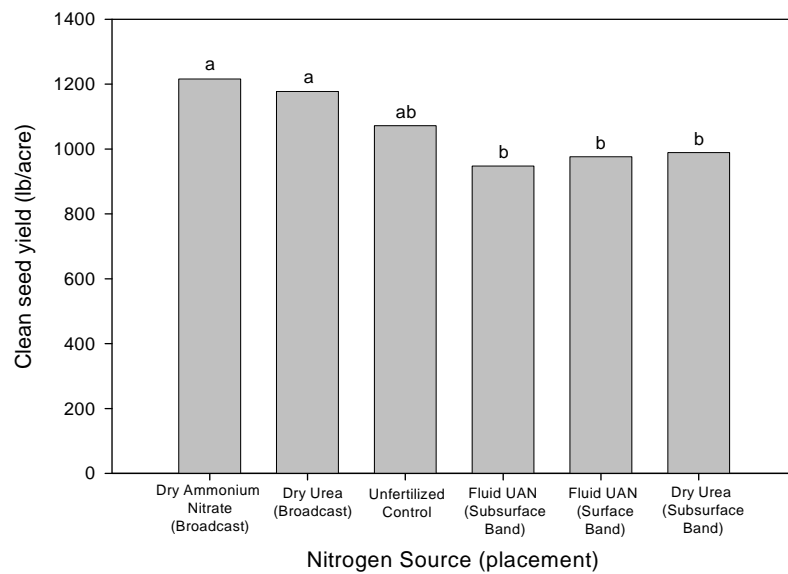
Figure 2. The effect of N source and placement (applied October 15, 2005) on grass seed yield in 2006. Bars capped with the same letter are not significantly different at the 5% level according to Tukey's HSD.

Yield and N recovery data from the multi-location experiments initiated in 2006 will not be available until summer 2007. Data characterizing the soil and physical environments, and in-field measurements of NH_3 volatilization, are presented here. On sunny days, surface temperatures were generally higher after the October 5, 2006 fertilizer application at the site where residue was burned, and frequently exceeded 90° F (Figure 3). On cloudy days, soil surface temperatures were more similar between the two locations. Soil and air temperatures after the November 15, 2006 fertilizer application were similar and below 60° F due to the later date and presence of continuous cloud cover (data not presented). Gravimetric soil moisture (0 to 6-inch depth) averaged 14% and 26% at the unburned site, and 4% and 18% at the burned site, for the October 5 and November 15 application dates, respectively. Bulk soil pH (1 ft depth) averaged 5.6 at the unburned site and 6.4 at the burned site. Surface soil pH measured with a microelectrode averaged 8.2 and 7.8 at the unburned site, and 7.9 and 6.2 at the burned site, for the October 5

and November 15 application dates, respectively. Results suggest bulk soil pH is considerably lower than pH measured at the surface, and support results from the lab study showing that bluegrass residue has a high pH. Interestingly, soil pH declined at the burned site between the first and second fertilizer application dates. Significant rain occurred between the first and second application dates, which may have led to dissolution and reaction of the alkaline ash with the underlying soil.
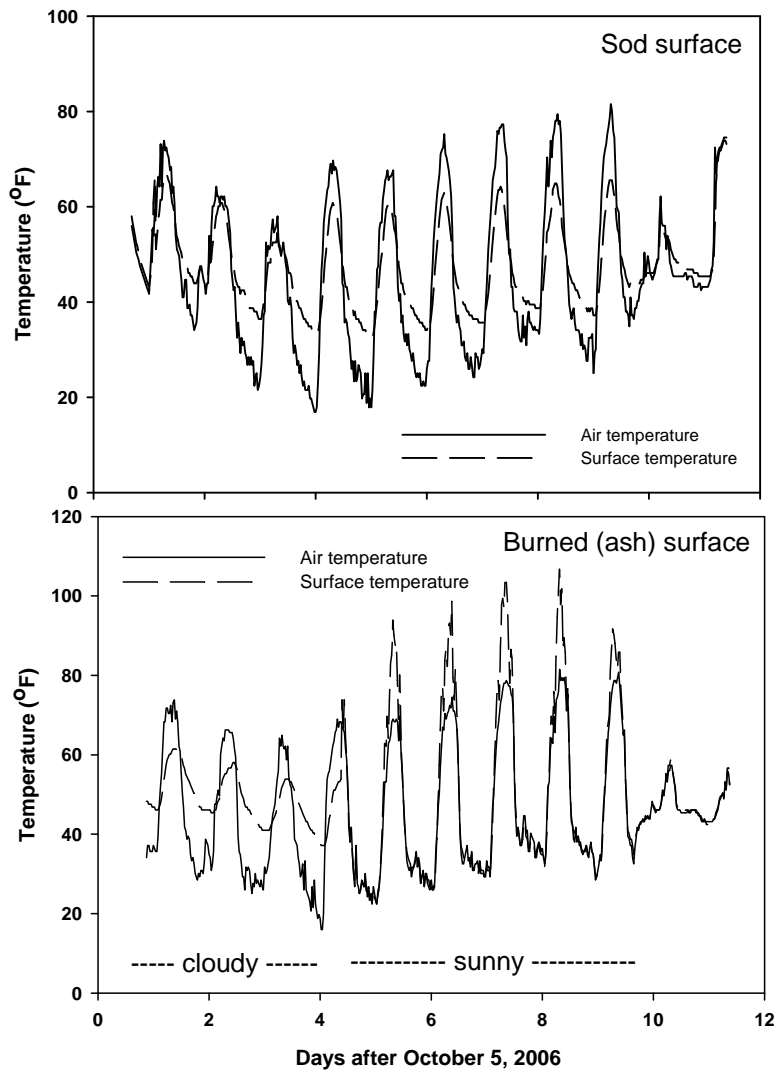
Figure 3. Soil surface and air temperatures following fertilizer application at field sites where residue was baled and removed (top) or burned (bottom). The sites are located approximately 30 miles from one another. Cloudy and sunny days indicated on the lower graph panel apply to both sites.

Collectively, results from the field trials suggest certain conditions at the burned site (high gravimetric moisture for the second application date, high temperature and surface pH for the first application date) may be conducive to higher NH_3 volatilization rates, while certain

conditions at the unburned site (high gravimetric moisture, pH, and urease activity) may also be conducive to high NH_3 volatilization rates. Measurements in the field showed that NH_3 volatilization was similar between locations but higher on average for urea and fluid UAN than for the control or ammonium nitrate applied on October 5 (Figure 4). For the November 15 application date rates of NH_3 volatilization were significantly higher for urea and fluid UAN than for the control or ammonium nitrate only at the site where the residue was not burned. The magnitude of NH_3 volatilization at the site with residue after the November 15 application was also nearly one order of magnitude higher than at the same site after the October 5 application. This suggests that conditions at the unburned site favor greater rates of NH_3 volatilization than at the burned site. Also, the higher soil moisture at the November 15 application apparently had a greater impact on NH_3 volatilization than the high temperature at the October 5 application.
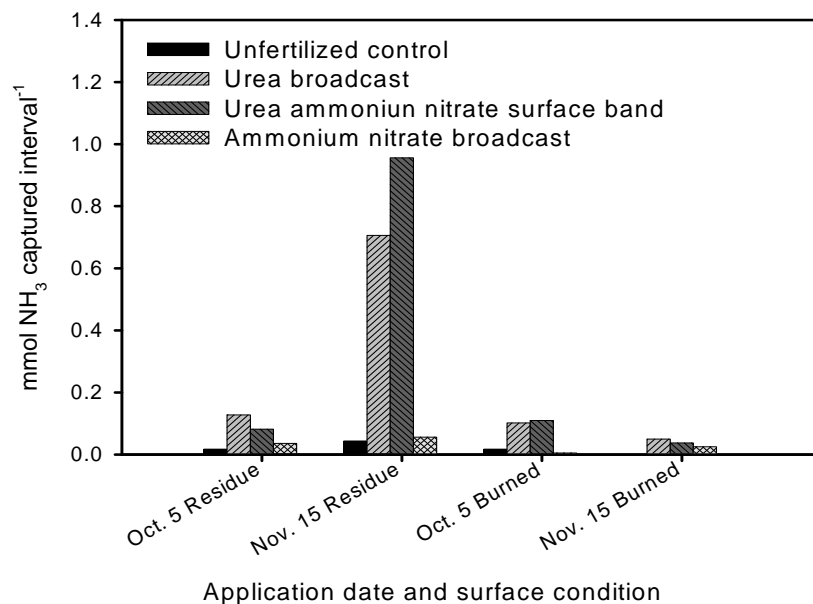
Figure 4. The effect of application date and surface condition (residue or burned residue) on NH_3 volatilization measured from different N sources in the field. There was a significant main effect of N source at the October 5 application date, with urea and fluid UAN resulting in significantly more NH_3 volatilization than the other sources. There was an interaction between N source and location at the November 15 application date, with urea and fluid UAN resulting in significantly more NH_3 volatilization than the other sources at the site with residue only.

LITERATURE CITED

Kissel, D.E. 1993. Management of urea fertilizers. North Central Regional Extension Publication #326, 12 p. Available online at: http://www.oznet.ksu.edu/library/crpsl2/NCR326.pdf

Koenig, R., M. Palmer, D. Miner, B. Miller and J. Harrison. 2005. Chemical amendments and process controls to reduce ammonia volatilization during in-house composting in high-rise, caged layer facilities. Compost Sci. Util. 13:141-149.

Terman, G.L. 1979. Volatilization losses of nitrogen as ammonia from surface-applied fertilizers, organic amendments, and crop residues. Adv. Agron. 31:189-223.

Torello, W.A. and D.J. Wehner. 1983. Urease activity in a Kentucky bluegrass turf. Agron J. 75:654-656.

PROCEEDINGS

OF THE

WESTERN NUTRIENT

MANAGEMENT CONFERENCE

Volume 7

MARCH 8-9, 2007
SALT LAKE CITY, UTAH

Program Chair:
John Hart
Oregon State University
Corvallis, OR
(541) 737-5714
john.hart@oregonstate.edu

Publicity Chair:
Richard Koenig
Washington State University
Pullman, WA
(509) 335-2726
richk@wsu.edu

Coordinator:
Phyllis Pates
International Plant Nutrition Institute
Brookings, SD
(605) 692-6280
ppates@ipni.net