# AMMONIA VOLATILIZATION

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## INTRODUCTION

Little work has been reported on the loss of ammonia from soils where fertilizers have been applied in an undisturbed environment. There are a multitude of studies that have used a chamber of some sort to estimate ammonia loss. The use of a chamber of some sort means that the environment has to be altered making the data derived suspect when translated into a loss number such as kg/ha. The advent of passive vertical flux method by Wood et al., 2000 at Aubrn University in Alabama, allows for the measurement of ammonia loss from fertilizer or manure applications without altering the environment.

Urea is especially vulnerable to ammonia volatilization because it hydrolyzes according to the following reaction by Kissel et al. (1988) before it is considered plant available:

$$\text{urea} + 2H_2O + H^+ \xrightarrow{\text{urease}} 2NH_4^+ + HCO_3^-$$

further reacting as:

$$HCO_3^- + H^+ \leftrightarrows CO_2(g) + H_2O \text{ and } NH_4^+ \leftrightarrows NH_3 + H^+$$

The consumption of $H^+$ during hydrolysis results in a pH increase (Zaman et al., 2008). Increased pH results in more $NH_3$ and increased volatilization (Kissel et al., 1988). Ammonia loss not only represents an agronomic loss of N, but it is also an environmental pollutant. Agriculture is responsible for an estimated 90% of anthropogenic ammonia emissions (Boyer et al., 2002), with 12% resulting from fertilizer application and the remainder from animal production (Ferm, 1998). Up to 85% of atmospheric $NH_3$ is deposited locally from where it originates (Boyer et al., 2002). The remaining 25% can be transported long distances as secondary aerosol particles (Schjoerring et al., 1992; Boyer et al., 2002).

Nitrogen loss reductions can be obtained through cultural practices or the use of specialty nitrogen products such as Agrotain (Agrotain International) and ESN (environmentally smart nitrogen, Agrium). Cultural reductions in ammonia volatilization can be accomplished by incorporating urea into the soil, either mechanically or with water (Malhi et al., 2003; Harper et al., 1983; Bouwmeester et al., 1985; Black et al., 1987; Mugusha and Pluth, 1995)

## METHODS

Three field studies and an incubation study were conducted in 2009 and 2010. For all field studies measurement of ammonia volatilization used the modified passive flux method (Wood et al, 2000; Vaio et al., 2008). This consists of a rotating mast placed at the center of each circular plot. A tripod which did not interfere with the rotation of the mast was placed on the mast in order to stabilize it during high wind events. Each mast was equipped with a passive flux sampler at five heights (0.45, 0.75, 1.50, 2.25, and 3.00 m; Leuning et al., 1985). Flux samplers were extracted by adding 2-mL deionized water and shaken for 10-minutes. Extracts were analyzed colormetrically for $NH_4$ (Sims et al., 1995).

Horizontal $NH_3$ flux ($F_x$, µg N m-2 s-1) for each flux sampler was calculated by

$$F_x = (C^*V)/(\pi r^2 K\Delta t) \qquad [1]$$

where C is the concentration of $NH_4$-N (µg N/ml) in deionized water used to extract sorbed $NH_4$-N, V is the volume of deionized water used for extraction (2mL), r is the radius of the hole in the disc on the nozzle (0.0005 m), K is a correction factor (0.77), and Δt is the time at which the sampler was exposed (s) (Schjoerring et al., 1992; Wood et al., 2000; Vaio et al., 2008). Net vertical flux ($F_y$, ug N m-2 s-1) from each plot was estimated by integrating each horizontal flux with vertical distance for each sampler accounted for

$$F_y=(1/R)\Sigma(F_{x,p}-F_{x,b})\Delta h \qquad [2]$$

where R is the radius of the plot (15-m), and Δh (m) is the vertical distance corresponding to each sampler.

### 2009 grass seed fields (4)

Four KBG (Kentucky bluegrass) fields had ammonium sulfate, urea and agrotain applied in the fall of 2009. Two had residue burned and tow had the residue harvested. The two fields that had the residue harvested had a miss-application of fertilizer and will not be reported. The two fields where the residue was burned each had three replications in a randomized block design Masts were erected and 112 kg N/ha applied. Samples were inserted into the masts immediately following fertilizer application. Ammonia volatilization was measured and loss calculated.

### 2010 wheat field (1)

The field was split into 18 wedges of $20^o$; each wedge contained a circular (30-m diameter) plot with urea surface-applied at 112 kg N/ha and with each plot separated by at least 100 m to avoid contamination of $NH_3$ between treatments. The pivot was programmed to irrigate wedges with 0.0, 1.25, 3.8, 7.6, 11.4, and 21.6-mm corresponding to treatments, with the treatments (112 kg N/ha) arranged in a randomized complete block design. A rain gauge was placed in each treatment wedge in order to record irrigation rate. Immediately after irrigation, measurement of ammonia volatilization commenced and continued for the next 23 days. Wheat was harvested from each treatment (0.126 $m^2$) at 23 DAA (days after application). Above-ground dry matter was measured and total N was analyzed.

Three of the irrigation treatments in addition to urea had Agrotain and OAC (organic acid comples of malic acid) applied.

### 2010 grass seed fields (5)

Five fields were set up for ammonia volatilization in three locations Madras (2) Oregon, Hermiston (2) Oregon and Pullman (1) Washington. Urea, Agrotain, UAN solution and CAN-27 (Yara) was applied in 30m circles at a rate of 168 kg N/ha. Each circle at each location had three replications. Ammonia volatilization was measured immediately following the fertilizer application. Only data from one Hermiston filed will be discussed here.

### Incubation Study

Soil at field capacity was collected from a winter wheat field at the Hermiston Agricultural Research and Extension Center in Hermiston, OR (soil was an Adkins coarse-loamy, mixed, superactive, mesic Xeric Haplocalcids, with pH 6.99) to a depth of 30cm. 0.65 kg of soil (roughly 0.5 kg dry soil) was placed into gallon Ziplock Freezer Bags. Urea, Agrotain, and OAC was added at a rate of 1.05 g N/kg soil. A drinking straw was inserted into the bag then zipped shut around the straw. Samples were placed in incubators at $4.4^OC$, $15.6\,^OC$ and $26.7^OC$. At 1, 3, 6, 13, 20, 28, 34, 48, 63, 76, and 104 DAA bags were sub-sampled and analyzed for ammonia.

## RESULTS

Ammonia volatilization was 16% to 60% of nitrogen applied depending on the fertilizer, field and environmental conditions (fig 1, 3 and 5). In all fields urea had the highest ammonia loss. In the irrigation trial OAC had similar ammonia loss to urea at the low irrigation rates (Fig. 4). At the high irrigation rate OAC had reduced ammonia loss compared to urea. Agrotain had the lowest ammonia loss across all fields and treatments. Most agrotain treatments were less than 5% loss of N applied. In the irrigation study ammonia loss for Agrotain was not effected by irrigation rate (Fig. 4). Soil pH was below 7.0 for all fields. The irrigation study under wheat lost 60% of nitrogen applied where no water or agrotain was applied. As irrigation rate increased ammonia loss decreased (Fig 2). It took about 13 mm of irrigation water to reduce ammonia loss by 90% in the irrigation study. The KBG field in 2009 (Fig 1) had 16% of nitrogen lost. We suspect this loss was reduced because over 13mm of rainfall fell between day 4 and 6. The rainfall was not as effective at reducing volatilization losses as irrigation.

Temperature has an effect on hydrolysis and the length of time that Agrotain is effective in the soil (Fig 4). Only two temperatures are shown in figure 4, the highest 26 C is not presented. Urea and OAC hydrolyzed nitrogen at identical rates to each other. Agrotain spread hydrolysis over 63 days at the low temperature and 28 days at the warmer temperature. For the high temperature it took 15 days to complete hydrolysis.

For nitrogen left on the surface soil pH is not as big a driver as we once thought. Urea has the capability to raise pH and increase volatilization. When urea is used the benefit of either incorporating with irrigation or the use of Agrotain, a urease inhibitor, should be considered.

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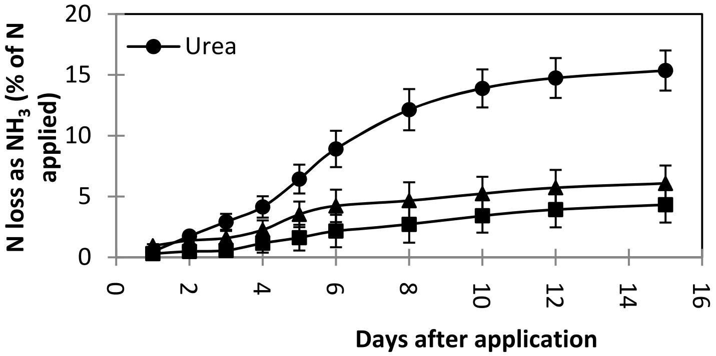

Figure 1. Cumulative loss of $NH_3$ during the period of 28 September to 13 October 2009 following application of 112 kg N/ha to Kentucky bluegrass as affected by N source.

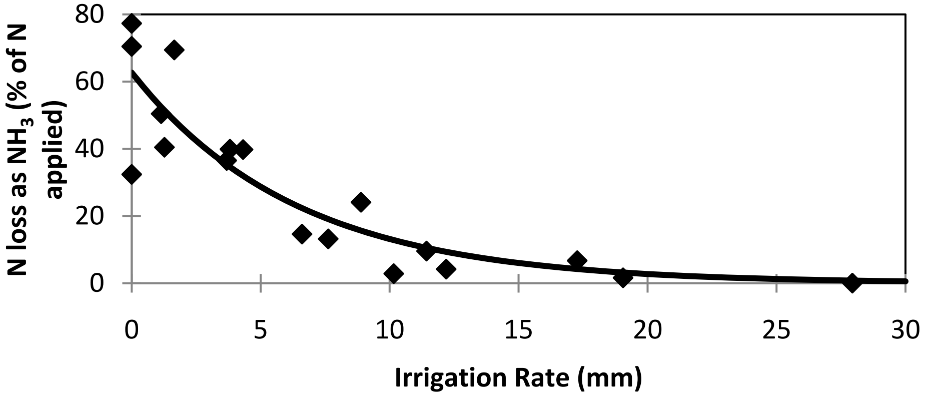

Figure 2. Cumulative loss of $NH_3$ during the period of 9 March to 2 April 2010 following application of 112 kg urea-N/ha to Winter Wheat as affected by rate of irrigation application.

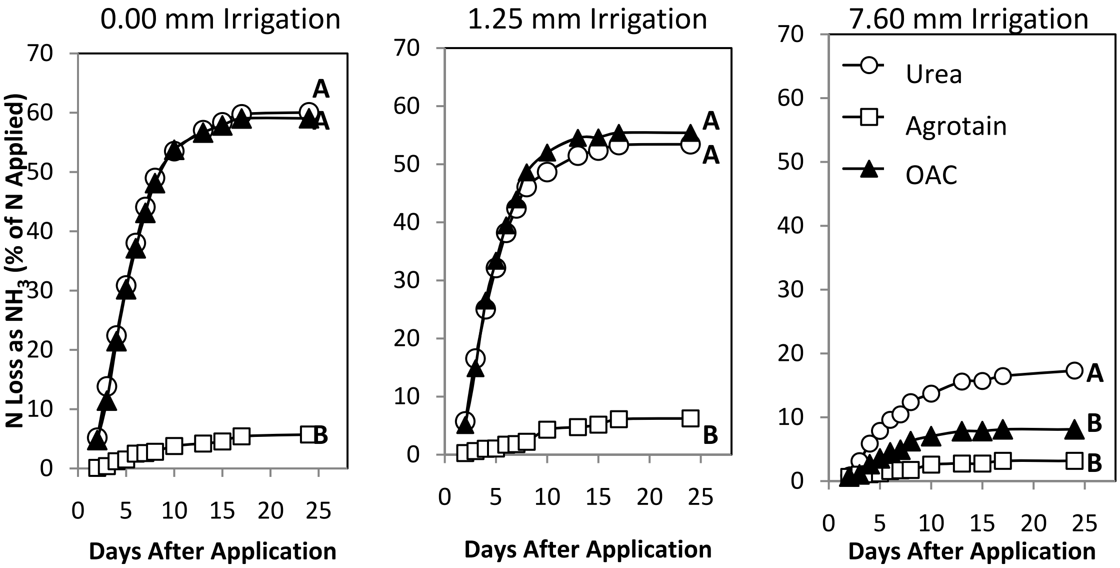

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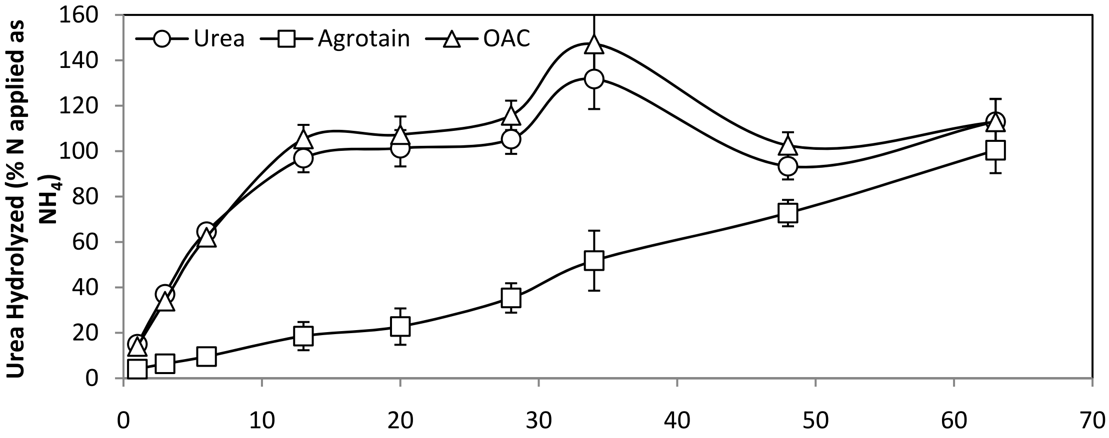
Figure 3. Cumulative loss of $NH_3$ within irrigation rates for the period of 9 March to 2 April 2010 following application of 112 kg N/ha to Winter Wheat for urea, Agrotain, and OAC.



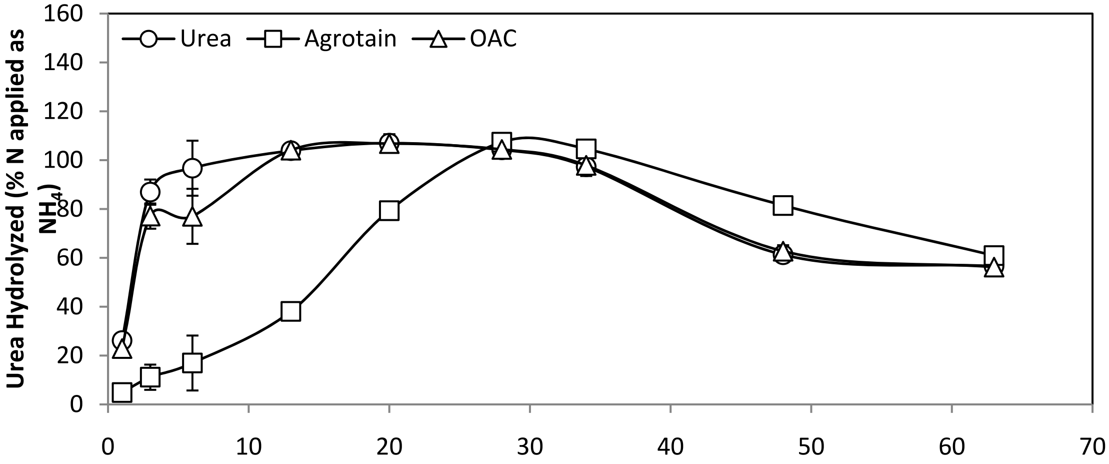


Figure 4. Formation of $NH_4$ in incubation as % N applied as $NH_4$, as affected by N treatment at incubation temperature (a) 4.4°C, (b) and 16.6°C. Bars represent standard error.

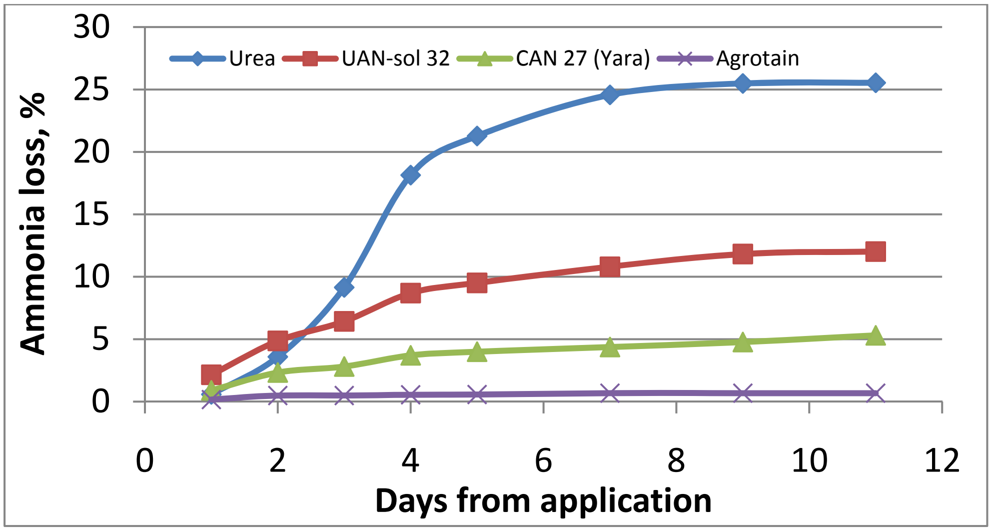


Figure 5. Ammonia loss for urea, UAN, Can-27 and Agrotain for fall of 2010 in Hermiston Oregon. Nitrogen applied at 168 kg N/ha

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