Nitrogen volatilisation losses - how much N is lost when applied in different formulations at different times

Graeme Schwenke, Adam Perfrement, Bill Manning and Guy McMullen

NSW Department of Primary Industries

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Take home messages

Fertiliser nitrogen can be lost from the soil surface as ammonia gas via the process of volatilisation. Just how much is lost depends on a range of factors, including; soil moisture, temperature, pH, naturally-occurring lime in the soil, ground cover, wind, soil clay %, and fertiliser type.

Nitrogen volatilisation losses from four top-dressed mid-tillering wheat crops were minor; <10% loss over a whole month during winter 2011. Fertiliser was applied to dry soil, temperatures were low, and there was little rain after application. There were only small differences between fertiliser types.

Two fallow paddocks broadcast with urea or ammonium sulphate in spring also had minor losses, except where ammonium sulphate was spread on a paddock with carbonates at the surface when losses were >30% of that added.

Two grass pasture paddocks broadcast with urea or ammonium sulphate in autumn or spring both had severe losses from urea (23-31% loss), but only minor loss from the ammonium sulphate.

Don't assume all applied fertiliser is lost if rain doesn't come after topdressing or broadcast spreading.

Avoid using ammonium sulphate on paddocks with carbonates in the surface soil.

Incorporation will prevent losses of any nitrogen fertiliser type.

Ammonium sulphate is less risky for grass pastures than urea if rainfall doesn't come soon after.

Background

It is well known that nitrogen fertilisers are 'safer' when incorporated than when surface spread, but pre-season broadcasting and in-season topdressing of wheat crops are practiced by many farmers in the region. Splitting nitrogen application between sowing and in-crop allows growers to lower their financial risk on fertiliser application by letting seasonal conditions drive decisions on how much to spend on nitrogen. Most people try to apply their fertiliser ahead of predicted rain, but what happens if it doesn't rain as predicted? Often, people assume the worst, but is the nitrogen really all lost into the air in a day or two? Worldwide, the research literature lists the range of measured losses from 0 to almost 100%, but there are very few instances of losses greater than about 40% of that applied, with most studies finding only around 10% loss. This extreme range of possible losses is due to the many factors involved in the process of volatilisation.

In the 2008 and 2009 GRDC advisor updates, we detailed the factors that drive the process of nitrogen volatilisation from fertiliser, along with the results of some laboratory incubation experiments (Schwenke et al. 2008, 2009). Here is a brief summary of the many factors involved;

(a) soil pH	- more loss at higher pH. Dissolving urea granule creates a high pH zone.
(b) Temperature	- the hotter it is, the greater the potential there is for ammonia loss.
(c) Soil moisture	- wet soil dissolves fertiliser but doesn't move N into the soil.
(d) Calcium carbonate	- lime in the soil reacts directly with ammonium sulphate increasing loss.
(e) Soil clay content	- clay in soils adsorbs ammonium nitrogen reducing potential for loss.
(f) Soil buffer capacity	- clays in soil absorb changes in soil pH.
(g) Biological activity	- ammonium is converted to nitrate which is safe from volatilisation
(h) Wind	- windy conditions lead to greater loss.
(i) Rain	- rain moves dissolved fertiliser into contact with soil clays, away from wind.
(j) Depth of fertiliser	- ammonia must be at the surface to volatilise. Incorporation reduces loss.
(k) Crop canopy	- some ammonia in air can be re-absorbed by a growing crop canopy.
(l) Residues/litter	- residues can strand fertiliser from soil. Urease enzyme present in residues.
(m) Fertiliser type	- only the ammonium form is lost. Urea converts to ammonium. Nitrate forms are not volatilised.

Our preliminary lab work highlighted the importance of some of these soil properties in setting the potential for nitrogen losses. However, actual nitrogen losses in the field are a function not just of risk factors but also process drivers, particularly soil moisture, wind speed, rainfall and temperature. While air movement and temperature effects can also be tested in the lab, field measurements are needed to see the actual amount of N that is lost through volatilisation in our region. Here we report on the first 6-months of measurements made in our 2-year GRDC and NSW DPI funded project. In 2011 we measured nitrogen volatilisation losses in 3 scenarios; (1) top-dressing wheat, (2) spring fallow broadcasting, and (3) autumn and spring fertiliser application to a grass pasture.

Methodology

We applied nitrogen fertilisers at locally relevant rates to 50-metre-diameter circular plots using either hand spreading (solid fertilisers) or a quad bike sprayer fitted with streaming-bar nozzles at 10 cm spacing (liquid fertilisers). Each fertiliser type was replicated three times at each paddock (except paddock 7). All plots at a paddock were separated by at least 100 metres to avoid cross contamination. Each paddock also had a background plot 200 metres from the nearest treatment plot, to measure any ammonia already in the air. We put a 3 metre tall mast at the centre of each circular plot and fitted ammonia capture tubes at five heights on the mast. The mast had a wind vane on top and rotated on bearings so that the capture tubes always faced into the wind. This way there was always 25 metres of fertilised plot ahead of the mast no matter which way the wind came from. We changed capture tubes every 3-4 days over a period of a month, measured the ammonia captured inside each, and tallied up the total amount of N lost as ammonia.

Results

Scenario 1: Topdressing wheat at mid-late tillering

We trialled 4 fertilisers on two soil types near Edgeroi in July (Paddocks 1 & 2), and 4 fertilisers on two paddocks near Mullaley in August (Paddocks 3 & 4). Figures 1 and 2 show that there were only minor volatilisation losses of N from all fertilisers trialled, despite very little rain in the weeks following fertiliser application (see Figures 1 and 2). Even at paddocks 3 & 4, most rain occurred in the last week of measurement. Volatilisation was likely limited by cool air temperatures, adsorption of ammonium onto soil clays, plant uptake (after rain), and crop canopy protection against wind at the surface. Although the losses were only small, there were differences between some of the products trialled. The liquid urea (normally used at a later growth stage, not on soil) tended to lose a little more than solid urea as it was applied in a dissolved form, whereas the urea particles had to wait for some rainfall to dissolve. However, being applied in liquid form also meant it had immediate contact with the soil particles to aid adsorption of the ammonium once converted from the urea form. The urea ammonium nitrate and ammonium nitrate liquids showed slightly smaller losses, because a portion of these products is already in the nitrate form which does not volatilise. When the products were considered on an ammonium basis the losses per unit ammonium were similar between products. At paddocks 3 & 4, the use of a nitrification inhibitor with urea (Green Urea ™) further reduced volatilisation compared to the standard urea.

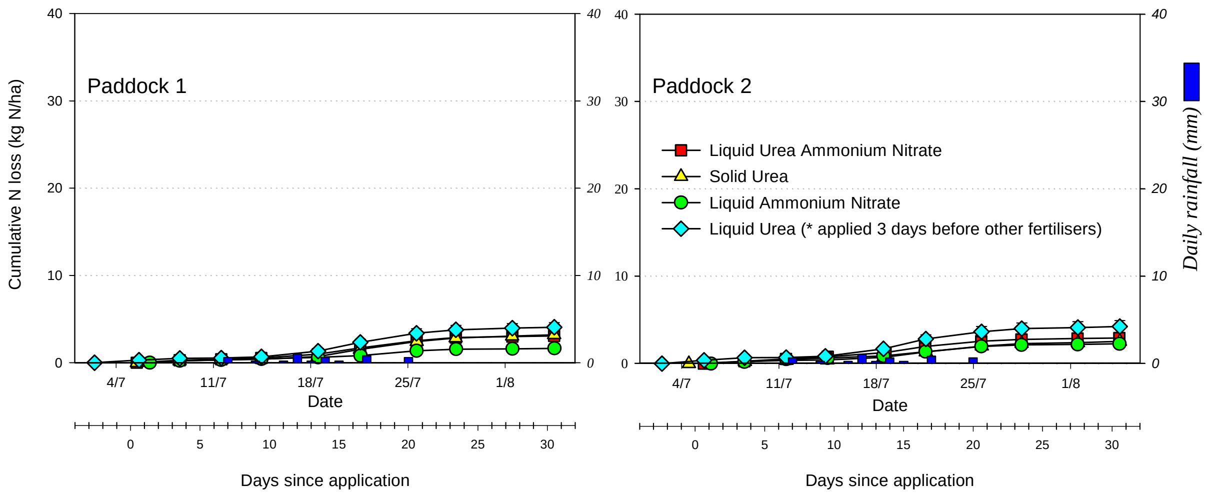

Figure 1. Cumulative nitrogen loss as ammonia after 60 kg N/ha topdress application into two paddocks near Edgeroi during July 2011. Each point is a mean of 3 replicate plots. Daily rainfall is shown as bars from top of graph.

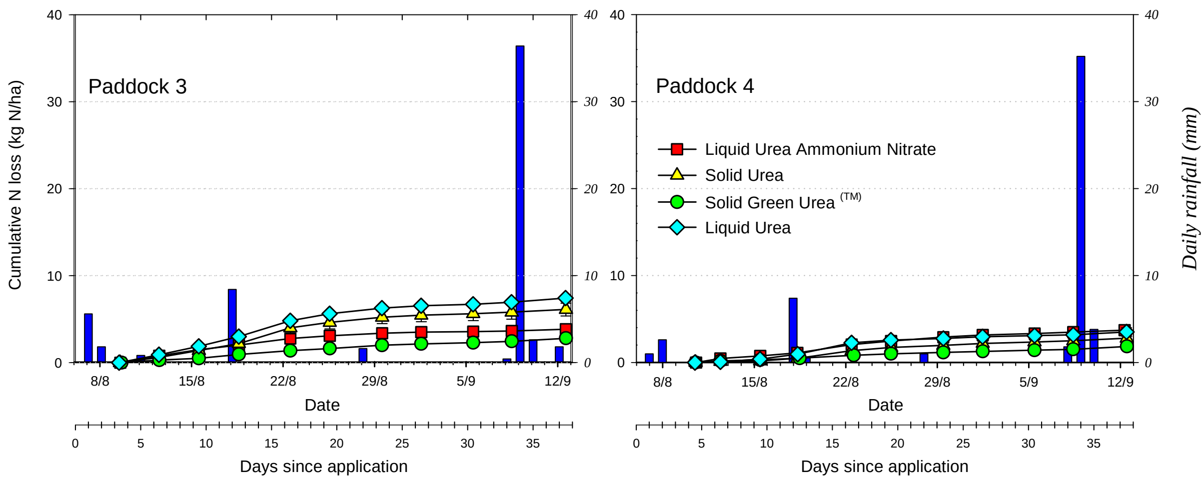

Figure 2. Cumulative nitrogen loss as ammonia after 80 kg N/ha topdress application into two paddocks near Mullaley during August-September 2011. Each point is a mean of 3 replicate plots. Daily rainfall is shown as bars from top of graph.

Scenario 2: Fertiliser broadcast onto fallowed soil prior to summer cropping

N volatilisation during the spring fallow can be higher as temperatures are warmer, rainfall events are more frequent (though sometimes small) and there is no crop to slow wind blowing across the soil surface. An added factor at paddock 5 was the observed/measured presence of carbonate nodules in the soil surface that can react directly with ammonium sulphate to stimulate greater N losses than would otherwise be the case. In these trials we had only urea and ammonium sulphate (crystalline byproduct) fertilisers as liquids are not used for pre-season nitrogen application. Volatilisation loss from ammonium sulphate was high (>30% of applied nitrogen) at paddock 5, due to the presence of the carbonates. After application of the fertilisers this site had enough rain to just dissolve the products which was followed by a dry period. Urea losses were also higher at this paddock. At paddock six the initial rain after spreading was higher and may have helped to get the dissolved nitrogen into better contact with the soil clays.

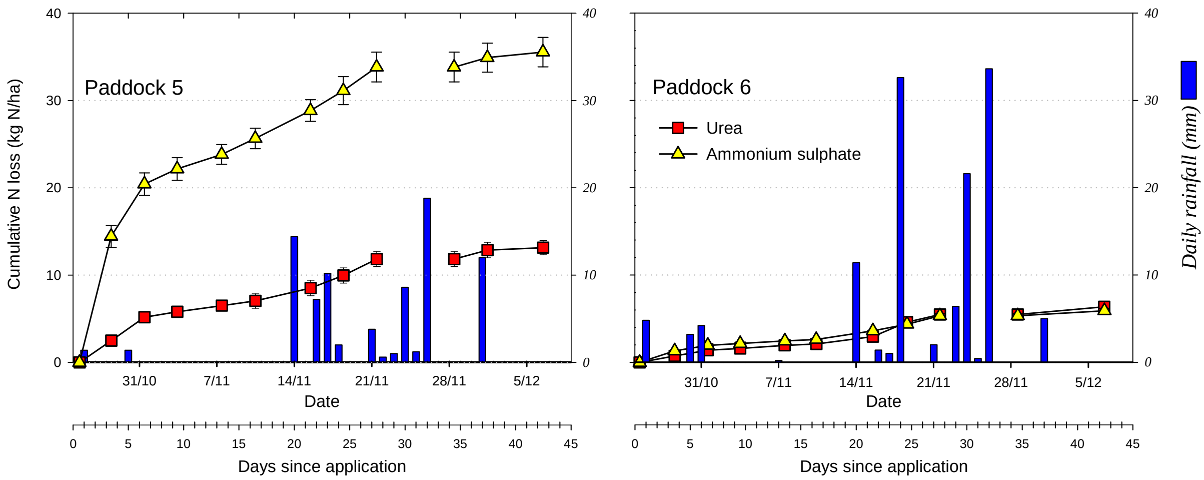

Figure 3. Cumulative nitrogen loss as ammonia after 100 kg N/ha broadcast application at two fallow paddocks near Caroona during November-December 2011. Each point is a mean of 3 replicate plots. Daily rainfall is shown as bars from top of graph. Gap in data due to storm damage.

Scenario 3: Fertiliser broadcast onto tropical grass pasture

We used a grass pasture near Tamworth to trial the method in autumn before the main trials began, and included a tropical grass pasture near Caroona in spring when measuring paddocks 5 & 6. Figure 4 shows that both pasture paddocks lost significant amounts of nitrogen from the urea application, but much less from the ammonium sulphate. In both instances we had little rain in the first two weeks following application, but urea granules soon disappeared from view. Without significant rainfall, the dissolved urea would have been caught in the leaf litter. Conversion of urea to ammonium needs an enzyme called urease, which is abundant on plant residue surfaces. The mulch layer also helps to keep conditions moist.

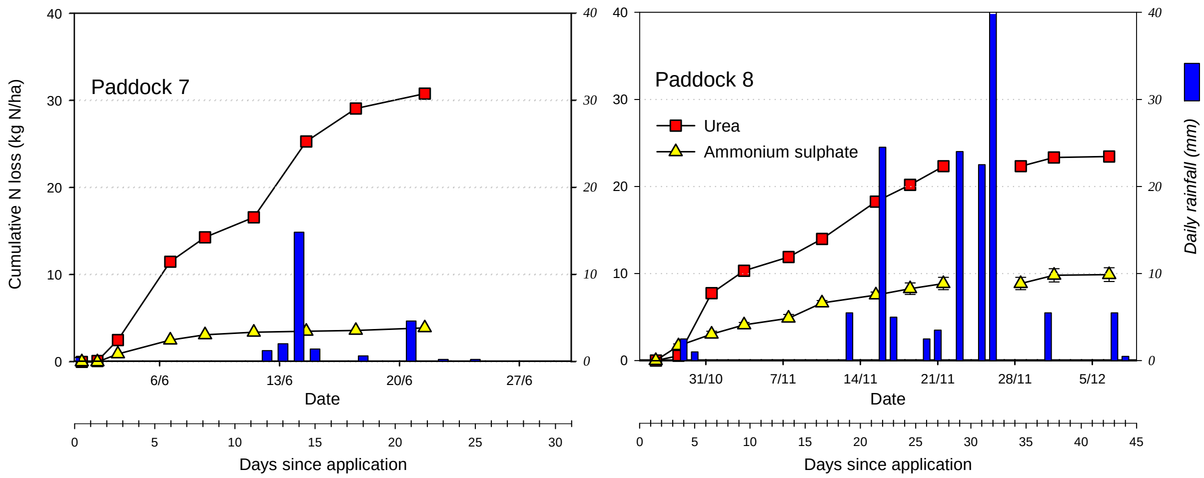

Figure 4. Cumulative nitrogen loss as ammonia after 100kg N/ha broadcast application at two grass pasture paddocks near Tamworth (paddock 7), and Caroona (paddock 8). Measurements were done during June (paddock 7), and November-December 2011 (paddock 8). There was only one plot of each treatment in paddock 7, but each point in paddock 8 is a mean of 3 replicate plots. Daily rainfall is shown as bars from top of graph. Gap in paddock 8 data due to storm damage.

These results will be added to over the next 12-18 months from further trials on other farm paddocks, giving a better overall picture of the amount of nitrogen losses likely in the region. So far, it appears that topdressing wheat paddocks during mid-tillering is relatively low risk in terms of volatilisation losses, so most of the applied nitrogen remains in place for crop uptake. Whether the topdressed nitrogen translates through to improved yield or protein will depend on the weather conditions for the remainder of the crop's growing season, as well as other influences such as weeds and diseases. Evaluating the impact of post-sowing nitrogen application was outside the scope of this project, but has been well researched in previous years. Research funded by GRDC and NSW DPI through the Northern Grower Alliance project (NGA0002) showed that delayed N reliably improved grain protein and maintained grain yield with applications up to early stem elongation, irrespective of the N fertiliser that was used.

Our first trials of summer fallow broadcast applications have shown that some losses are to be expected, but are mostly minor (<10%), unless the soil surface has naturally-occurring lime where losses can be much higher. However, in our searches for suitable trial sites across the region it appears that naturally occurring lime in the surface soil is fairly rare. If in doubt you can ask for a calcium carbonate test when soil testing – once will generally be sufficient as it won't change with seasons. However, cultivation can bring up lime from lower in the soil profile.

In general our results so far seem to fit well with the research literature where an average of 10% of applied nitrogen is lost from urea added to arable systems and 20% from urea added to pastures.

Acknowledgements

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Contact details

Graeme Schwenke
NSW Department of Primary Industries
Phone: 0267631137
Email: graeme.schwenke@industry.nsw.gov.au

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