Ammonia volatilisation losses from fertilisers surface-applied to vertosols in the northern Australian grains region

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Abstract
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 speed and direction, soil clay %, and fertiliser type. Nitrogen volatilisation losses from four top-dressed mid-tillering wheat crops measured during winter 2011 were minor; <10% loss over a whole month. Liquid urea, liquid urea ammonium nitrate, liquid ammonium nitrate, solid urea and solid urea coated with urease inhibitor were 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. So far, application of N fertilisers to neutral-alkaline clay soils appears to be relatively low risk for N loss by volatilisation.

Introduction
With increasing fertiliser prices, farmers can ill afford to apply nitrogen (N) fertiliser that may be lost to the air before it can be used by the crop. Farmers in the northern grains region of Australia traditionally incorporate N fertiliser into the soil either prior to, or at the time of sowing of a cereal crop such as wheat, barley or sorghum. Post-sowing surface application of N fertiliser to winter-growing crops has not often been practiced in this region as winter rainfall is highly variable. However, this high variability has driven greater interest in split N fertiliser application, with part applied at sowing and more applied later during crop growth if seasonal conditions are favourable.

Two emerging trends in N fertiliser use in the region prompted the current research; *viz.* pre-sow surface spreading of by-product ammonium sulphate (from gas purification of coke ovens at steelwork industries), and post-sow surface application of urea or liquid N products ahead of forecast rainfall events. While it is well known that ammonia volatilisation is governed by soil properties, weather conditions, and agricultural practices, there is no data on the magnitude of N volatilisation losses occurring in the region. Our aim is to measure N volatilisation from fertilisers applied both pre-crop and in-crop in farmer's paddocks. The results should lead to better informed N fertiliser management for cereal production. In this paper we report here results from four in-crop N fertiliser applications to wheat crops, and two spring fallow applications (post summer crop).

Material and Methods
The dominant cropping soils of the region are neutral to alkaline, deep cracking clays (vertosols) of moderate to high clay content (30-60% clay), found on flat, open plains and gently undulating slopes. Some localised areas have naturally-occurring lime at the surface (<10% lime) (Singh *et al.* 2003). We measured ammonia volatilisation loss with a modified integrated horizontal passive flux method (Wood *et al*. 2000), which consists of 5 glass tube samplers attached at various heights to a freely-rotating mast at the centre of a 50 m diameter circular plot. Treated plots were separated from each other by >100 m to avoid cross-contamination. A background mast was located 200 m upwind of the treated plots at each site. Treatments were arranged in a randomized complete block design with 3 replications. Fertilisers trialled in-crop at the mid-tillering growth stage included; urea (U), liquid urea (LU), liquid urea ammonium nitrate (UAN), liquid ammonium nitrate (LAN), and green urea ™ (GU; urea coated with N-(n-butyl) thiophosphoric triamide, a urease inhibitor). We applied solid fertiliser products by hand spreading and liquid products using a quad bike sprayer fitted with streaming-bar nozzles. Only urea and ammonium sulphate (AS) were used in the fallow paddocks. Nitrogen rates used reflected local farmer practice; 60-80 kg N/ha in-crop, 100 kg N/ha for fallow application. Fertiliser was applied at paddocks 1 and 2 on 5/6/2011, paddocks 3 and 4 on 9/8/2011, and paddocks 5 and 6 on 25/10/2011.

Results and Discussion

Ammonia volatilisation from fertilisers applied in-crop to four wheat crops was minor with all cumulative losses less than 10% of that applied over a month after spreading (Table 1; paddocks 1-4). There were statistically significant differences between N fertiliser products at 3 of the 4 in-crop paddocks, with the ammonia lost from LAN less than other products at paddock 1, and GU less than U at paddock 3 and less than LU at paddock 4. These low level losses and minor product differences would enable farmers to choose a fertiliser product based on ease of handling and cost, rather than perceived differences in N volatilisation losses. In contrast, losses from fertilisers applied to one fallow paddock (paddock 5) during warmer conditions were more severe when ammonium sulphate was used, most likely due to the presence of natural lime at the surface. The other fallow paddock (paddock 6) showed only minor losses and no fertiliser product difference, but this may have been due to greater rainfall soon after application.

Table 1. Cumulative N volatilisation losses as a proportion of the N applied in fertilisers to 6 paddocks during 2011. Paddocks 1-4 were wheat paddocks at mid-tillering growth stage, paddocks 5-6 were fallow paddocks sampled in spring. Abbreviations for fertiliser products are given in the text. Results from within a paddock that are followed by the same letter were not significantly different.

Paddock	N rate (kg N/ha)	Days measured	Av Temp (^oC)	Rainfall (mm) 0-7 days	Rainfall (mm) >7 days	U	LU	UAN	LAN	GU	AS
							(Cumulative N loss as % of N applied)				
1	60	30	9.6	0.6	4.4	5.3b	6.7b	5.2b	2.7a	-	-
2	60	30	9.6	0.6	4.4	5.2	6.9	4.9	3.8	-	-
3	80	34	11.9	0.8	52	7.6b	9.3b	4.9a	-	3.5a	-
4	80	34	11.2	0.0	50	3.5ab	4.4b	4.6b	-	2.3a	-
5	100	27	20.4	2.8	40	14.0a	-	-	-	-	36.7b
6	100	27	20.5	12	61	6.9	-	-	-	-	6.7

Farmers in the region are hesitant to apply N fertiliser in-crop unless the probability of receiving rainfall soon after spreading is high, but predicted rain may still not eventuate or be less than anticipated. The anticipated rain is important not only for lowering the volatilisation risk for surface-spread fertilisers, but also for promoting plant growth to take up the applied N. Our in-crop results showed only minor losses of N despite very little rain over the following weeks to incorporate the applied fertilisers. Even at paddocks 3 and 4, most rain occurred in the last week of measurement. Separate plant tissue N measurements (not shown) made on plants collected at the completion of the 1 month measurement period showed no significant increase in tissue N concentration as a result of surface fertiliser use. This indicates that little N uptake had occurred in the month of air sample measurements, probably due to the dry and cold conditions, so most of the N from applied fertiliser was retained in the soil. Volatilisation was likely limited by rapid adsorption of ammonium onto clay mineral exchange surfaces, high soil pH buffering capacity, and crop canopy protection against wind at the surface (Freney *et al.* 1983). Use of the nitrification inhibitor with urea further reduced volatilisation by retaining the added N in the urea form for longer.

In contrast, N volatilisation during the spring fallow can be higher as temperatures are warmer, rainfall events are more frequent (though still sometimes small) and there is no crop to slow wind over the soil surface. An added factor at paddock 5 was the observed presence of lime concretions in the soil surface. Lime can react directly with ammonium sulphate to stimulate greater N losses than would otherwise be the case (Freney *et al.* 1983). Soil testing of this site found an average of 11% calcium carbonate in the soil, compared to just 0.1% at all other paddocks.

Conclusions

From the first year's field results, in-crop winter application of N fertilisers in the Australian northern grains region appears to be a relatively low risk practice, even when predicted follow-up rainfall does not occur. However, more severe losses can occur in fallow paddocks after spring surface N application where ammonium sulphate is used on soils with naturally-occurring lime present at the soil surface.

References

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