Ammonia volatilisation from urea fertiliser products applied to an alkaline soil

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Abstract

A static chamber system was used to measure the levels of ammonia volatilisation from 7 urea-based fertiliser products and one non-urea based nitrogen fertiliser, applied to the surface of a Calcixerollic xerochrept. Ammonium sulfate, urea, urea coated with sulfur (2 levels), urea coated with polymer (2 levels) and zinc-coated urea (2 levels) were applied to the surface of the alkaline soil and incubated in sealed jars for 4 and 7 days. Ammonia volatilisation levels varied from 4.9% for ammonium sulfate to 7.9% for one of the zinc-coated urea products, after 7 days of incubation. There was no significant difference between urea and any of the urea-coated fertilisers. Significantly higher levels of ammonia were volatilised after 7 days compared to 4 days. The levels of volatilisation were low compared with other studies, possibly caused by low levels of urease activity in the soil used. In addition, the lack of inhibition of volatilisation by the surface-coated fertilisers was in contrast to previous findings.

Key Words

Ammonia volatilisation, urea; sulfur, polymer.

Introduction

Reviews of gaseous nitrogen emissions from fertiliser products (Harrison and Webb 2001; Sommer *et al.* 2004) have indicated the serious consequences of agriculture on global emissions. These include acidification of soils and eutrophication of waters from rainfall deposition (Draaijers *et al.* 1989, Harrison and Webb 2001; Sommer *et al.* 2004). The other result of atmospheric losses is the effect on farmers in terms of reduced nitrogen use efficiency in soil nutrient transport. This may encourage higher rates of usage of nitrogen fertiliser to compensate for losses associated with its application. Alternatively, there may be a more recent trend to reduce levels of fertiliser use and encourage more efficient utilisation (Sommer *et al.* 2004). Globally, urea has been the most used form of nitrogen fertiliser accounting for 46% of all usage (Watson 2000) because it is the cheapest form of solid N fertiliser to produce and has the highest N content. However it is also one of the more inefficient forms of N fertiliser owing to losses, which have been reported to occur by NH_3 volatilisation. The levels of NH_3 release reported vary considerably, and factors such as temperature, soil pH, soil and atmospheric moisture, wind velocity and soil organic carbon levels all add to the complexity of the process. Previous studies have involved a range of techniques performed in both laboratory and field situations (Fenn and Hossner 1985; Gameh *et al.* 1990; Gioacchini *et al.* 2002; Sigunda *et al.* 2002; Sommer *et al.* 2004; Zaman *et al.* 2008). In attempts to reduce losses through NH_3 volatilisation various coatings and treatment have been applied to urea and other N fertilisers include polymers (Blaise and Prasad 1995; Rochette *et al.* 2009a), elemental S (Prasad 1976; Knight *et al.* 2007), urease and nitrification inhibitors (Gioacchini *et al.* 2002; Asing *et al.* 2008, Zaman *et al.* 2008). This study aimed to quantify the effect of different urea granule surface treatments on the extent of ammonia volatilisation on a calcareous soil.

Methods

Soil

A Calcixerollic xerochrept from Cungena, South Australia was used in this study. A sample from the 0-10 cm depth layer of this soil was air dried and sieved to <2.0 mm prior to use. This soil had the following chemical properties: Total C 4.9 mg C/g soil; organic C 0.6 mg C/g soil; $CaCO_3$ 35.7 %; pH (1:5 soil:water) 8.4.

Fertilisers

Eight fertilisers were used in this study: ammonium sulphate (AS), urea (U), sulfur-coated urea 5% (US 5%), sulfur-coated urea 10% (US 10%), polymer-coated urea 2L/t (UP 2L), polymer-coated urea 4L/t (UP 4L), zinc sulphate-coated urea 0.8% Zn (ACT 117) and Zn:PEI-coated urea 1.0% Zn (ACT 118).

Incubation experiment

Experiments were conducted using glass jars of approximately 800 mL capacity (Ball® Quart Wide Mouth Jar, Alltrista Consumer Products Company) fitted with gas-tight lids. The lids were fitted with a stainless steel septum port containing a gas tight rubber septum through which a needle could be inserted. The Cungena soil (17 g) was packed to a bulk density of 1.4 g cm^{-3} in individual PVC cores (37 mm ID x 50 mm high) fitted with nylon mesh (0.75 µm, Australian Filter Specialists) at their base. The packed soils were adjusted to 70% water filled pore space (WFPS). Individual soil cores were placed into the incubation jars together with a polycarbonate vial containing 10 mL of reverse osmosis water to help maintain headspace humidity and reduce any drying of the soil. The soil samples were pre-incubated for 7 days at 25°C prior to imposing fertiliser treatments. Weighed fertiliser granules were placed on the surface of the soil cores. A 40 mL polycarbonate vial containing 20 mL of 0.5 M $KHSO_4$ was placed in each jar with the soil samples to trap any ammonia that would volatilise and the jars were resealed. The fertiliser products used contained different concentrations of nitrogen and the mass of fertiliser added to each core was adjusted to give an addition of approximately 12 mg N / core (equivalent to 100 kg N / ha).

A full factorial design with four replicates of each combination of 10 fertiliser treatments and two incubation times (4 and 7 days) was used, and an incubation temperature of 25°C was maintained throughout. The fertiliser treatments included the application of individual granules from each of the eight fertilisers as well as a no soil control treatment and a soil with no fertiliser treatment. An additional 12 jars were prepared in which duplicate 0, 1, 2, 3, 4 or 5 mL volumes of 0.5 M $(NH_4)_2SO_4$ were injected into 10 mL of 1 M NaOH in the same trapping system. A further 6 jars in which duplicate 0, 2 or 4 mL volumes were directly injected into 20 mL of 0.5M $KHSO_4$ solution were also included. These series of jars were used as controls to ensure that the incubation system was quantitatively trapping ammonia. The $KHSO_4$ ammonia trapping solutions were removed from half the jars after 4 days of incubation and from the remaining jars after 7 days. Aliquots of the $KHSO_4$ solution (2 mL) were removed from the ammonia traps and added to 8 mL of reverse osmosis water. The ammonium concentration of the diluted samples was determined using an automated segmented flow analyser (Alpkem Flow Solution 3) and used to calculate the proportion of applied fertiliser N that volatilised.

Statistical analysis

A two-way ANOVA was used to determine the effects of the ten fertiliser treatments x two incubation times on ammonium recovery in the trap solution. Significant differences ($P \leq 0.05$) between means were identified using a Tukey's HSD multiple comparison technique. All analyses were completed using GenStat 12th Edition (Payne *et al.* 2009) or Statistica Version 8 (StatSoft 2007).

Results

Recovery of ammonia where solutions of ammonium sulphate were injected directly into the $KHSO_4$ traps and injected into an alkaline solution were quantitative ranging from 100.9 to 106.1%. This result confirmed the ability of the experimental apparatus to capture any ammonia volatilised from the soils amended with N fertilisers.

For the Cungena soil, the main effects of fertiliser type and incubation time were significant but the interaction between fertiliser type and incubation time was not (
Table **2**). No ammonia was volatilised from the unamended Cungena soil. Volatilisation from ammonium sulfate on Cungena soil was 4.9% which was significantly less ($P<0.05$) than from all the other fertilisers (Figure 1a). Losses from urea compounds ranged from 6.5 to 7.9% of applied N. There was no significant difference in volatilisation between urea and urea plus sulfur (US 5%), urea plus polymer (UP 2L and UP 4L) and urea product ACT 118. However, volatilisation was significantly higher for urea plus sulfur (US 10%) and for product ACT 117. Mean volatilisation after 4 days incubation was 5.7% of applied N, which was significantly lower than 7.9% after 7 days incubation ($P<0.001$) (Figure 1b).

Table 2. *P*-values derived from the ANOVA completed for the proportion of added fertiliser N that volatilised from the Cungena soil.

ANOVA Effect	Cungena soil
Fertiliser type	<0.001
Incubation duration	<0.001
Fertiliser type x duration	0.192

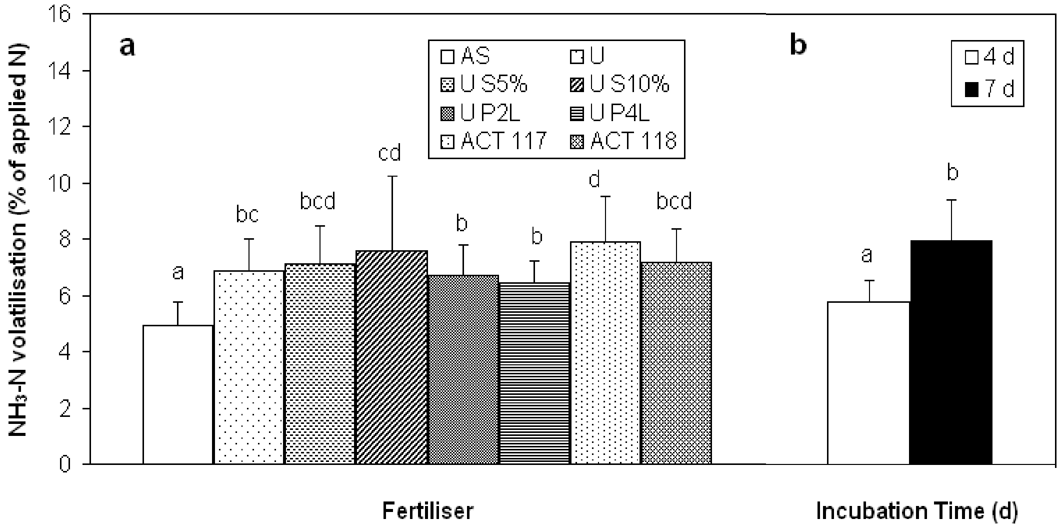

Figure 1. Ammonia volatilisation from 8 fertiliser products applied to Cungena soil and incubated for 4 or 7 days. Explanation of symbols is found in Methods section. NH_3-N recovery is expressed as the % of applied N that was volatilised. (a) the main effect of fertiliser type and (b) the main effect of incubation duration. Bars indicate ±1 standard deviation of the mean (n=4). Letters denote significant differences between means of each fertiliser type within each incubation period (*P*=0.05).

The levels of volatilisation from all fertiliser treatments shown in this experiment are at the lower end of results reported elsewhere (Fenn and Hossner 1985; Harrison and Webb 2001; Sommer *et al.* 2004). Maximum losses from Cungena soil were 7.9% of applied N. Gameh *et al.* (1990), in a laboratory chamber study, reported losses of up to 28% of added N from one soil, while around fourfold less N was lost from a second soil. It was suggested that the lower levels of volatilisation in that study were caused by lower air exchange rates compared with other studies, but that the relative treatment effects should still remain valid. Almost all volatilisation had occurred after 7 days for fertilisers applied to Cungena soil. Similar N losses of 9% were reported from a field study by Rochette *et al.* (2009a) for urea surface broadcast over a dry acidic soil with an incubation time of 25 days. Using a similar soil, but this time as intact cores in a laboratory chamber experiment, Rochette *et al.* (2009b) reported N losses of 21% from no tilled treatments but only 4% from traditionally ploughed treatments. Urease activity was observed to be higher in the no till soils, while the presence of residues on the surface of the no till soil prevented contact of the urea granules with the soil and that may have reduced adsorption of NH_4^+ on soil particles. The low organic carbon levels in the Cungena soil may also have resulted in low urease activity and consequently low volatilisation in this soil.

There was no evidence of inhibition of volatilisation by any of the products containing sulfur, polymer or zinc coatings. This contrasts with previous findings of a volatilisation reduction of up to 40% over urea levels, from polymer-coated urea (Blaise and Prasad 1995). Rochette *et al.* (2009a) showed a reduction from 9% volatilisation with urea to 4% from a polymer-coated product, and Knight *et al.* (2007) reported a polymer compound which showed zero volatilisation. Reductions in urea volatilisation levels ranging from 23% to 61% have reported for sulfur coated urea (Prasad 1976; Knight *et al.* 2007).

Conclusions

The levels of volatilisation from this experiment were low compared with those from published studies, ranging from 4.9% to 7.9%. All urea products showed significantly higher volatilisation than ammonium sulfate. Urea products coated with sulfur (10%) and with zinc (0.8%) showed significantly higher levels of volatilisation compared to uncoated urea. There were no coated products that indicated reduced volatilisation compared to uncoated urea. Volatilisation levels increased after 4 days to near maximum levels after 7 days. Low urease activity, which may occur in this soil because of its low organic carbon levels, could have contributed to the low levels of ammonia volatilisation reported here.

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