SHORT NON-REFEREED PAPER

AMMONIA VOLATILISATION LOSSES FROM NITROGEN FERTILISERS: LABORATORY STUDIES

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Abstract

Urea is the most widely used N fertiliser in the sugar industry, due largely to its high N concentration (46%) and lower price per unit of N compared to other fertilisers. The potential, however, for substantial amounts of N to be lost from field-applied urea by ammonia volatilisation remains a serious concern. Currently, several urea-based products claiming to have higher nitrogen use efficiency are actively marketed in the sugar industry. This study compared ammonia volatilisation losses from four fertilisers under controlled laboratory conditions. The fertilisers used were urea, limestone ammonium nitrate (LAN), a coated urea (Product A) and urea treated with a urease inhibitor (Product B). The soils which were included represented either properties favouring volatilisation losses (sandy, high pH) or properties not conducive to high losses (loam, low pH). Additional treatments included the influence of surface-applied lime and trash. Under all treatments, lowest N losses were from LAN (0.2 to 2.1% of N applied as fertiliser), and highest losses from urea (3.8 to 31.2% N loss, with liming and trashing significantly increasing losses). On the low pH loam soil, N losses from products A and B were significantly less than from urea. However, on a sandy, high pH soil (high volatilisation risk) losses from Product A were similar to those from urea, whereas Product B had slightly lower losses than urea. Surface-applied lime and trash increased losses from urea-based products. Consideration is given to the implications of these findings in terms of the selection of the most cost-effective N fertilisers for sugarcane on various soil types.

Keywords: N management, N fertilisers, N volatilisation, cost efficiency

Introduction

In the South African sugar industry, urea is the preferred N fertiliser, mainly due to a high N concentration (46%) and a lower price per unit N compared with limestone ammonium nitrate (LAN, 28% N) and ammonium sulfate (AS, 21% N). LAN and AS are nitrogen sources with little or no surface volatilisation loss of N when applied to most soils (Schumann, 2000). For urea, however, when surface-applied, significant quantities of N as ammonia may be lost through volatilisation.

Ammonia volatilisation can reduce the economic efficiency of N use by up to 50% (Sommer *et al*., 2004). In addition, decomposition of atmospheric ammonia can cause harmful effects in ecosystems. These effects include over-enrichment of N in sensitive aquatic ecosystems, while eutrophication of surface waters can lead to the decline of aquatic species, including those with commercial value, and an overall decrease in biological diversity (Krupa, 2003; Kurvits and Marta, 1998).

The extent of ammonia volatilisation depends on several environmental factors, including temperature, pH, soil moisture content, soil texture and the amount of surface residues. Losses are accelerated on warm moist soils, by a high surface pH and surface organic matter such as a trash blanket. For the conventional fertiliser products these relationships have been investigated by Schumann (2000) and Nixon *et al*. (2005) and the profitability of other more expensive N fertilisers have been calculated and compared to urea. Based on these findings, the Fertiliser Advisory Service (FAS) at the South African Sugarcane Research Institute (SASRI) rates soils for their volatilisation risk (Meyer *et al*., 2007). In addition, best management practices have been published which do not recommend the usage of urea on trashed soils or after lime application (Meyer, 2001).

New urea products on the market promise to be less volatile and allow a better N utilisation by the crop (Van Vuuren and Claasen, 2009); however, their price per unit N is higher than that of urea. Research is currently underway to compare the efficacies of the various N fertilisers in laboratory studies and field trials. The field trial results are not yet available, and the current paper deals with the results of the laboratory study.

Materials and Methods

The laboratory trial used the ammonia gas trapping method described by Nixon *et al*.(2005). Soil (3 kg dry weight) was adjusted with distilled water to 50% of its water holding capacity (WHC) and placed in 5 L closable plastic containers and incubated at 25°C. The lids of the plastic pots were prepared with air inlets and outlets. The outlets were connected by a pipe system via acid traps to a vacuum pump. Air was drawn continuously from the pots through an ammonia acid trap (0.1 N sulphuric acid). The traps were removed and replaced every two to three days. Analysis of the trapped N was by an automated colorimetric N analyser. Nitrogen fertilisers included in the study, urea, LAN, a coated urea (Product A) and urea treated with a urease inhibitor (Product B), were applied at a rate equivalent to 160 kg N/ha. Additional treatments were (soil pH refers to measurement in 0.01 *M* $CaCl_2$):

Trial 1: Clay vs sandy loam (clay soil 38% clay, pH 7.16; sandy loam soil 25% clay, pH 4.76).

Trial 2: Sandy soil (15% clay, pH 6.82, high volatilisation risk soil) under dry (adjusted to 30% WHC at the start) and moist regimes (adjusted to 30% WHC + application of 20 ml water = 1 mm ‘rainfall’ at the start and every two days).

Trial 3: Lime vs no lime (sandy soil 11% clay, pH 3.94, with an equivalent of 5 t/ha lime applied four weeks prior to fertiliser application.

Trial 4: Trashed (surface residues) vs bare (soil 41.5% clay, pH 5.29, trashed treatments covered with an equivalent of 5 t/ha sugarcane trash).

Each treatment was replicated six times in a randomised block design, with no-fertiliser controls being included. Incubation time was one month, with a total of 10 trap measurements during the time period. Genstat was used for all statistical calculations. As an indicator for evaluating the cost effectiveness of the products, the price per kg N after volatilisation losses was calculated, with the N content in the respective fertilisers being reduced by the measured loss.

Results and Discussion

The results of all laboratory trials are presented in Table 1. In the first trial, the four N fertilisers were used on two different soils of low volatilisation risk. Highest losses were with urea (5.01-5.58% of the applied amount), followed by Product A (3.38-3.73%) and Product B (1.79-2.24%). The lowest losses were with LAN, with only 0.02% on the sandy loam and 0.58% on the clay soil. Averaged across both soils, N losses for Product A were 33.0% lower than for urea and for Product B 62.0% lower. Taking into account losses, urea and Product B had the lowest cost per unit N of all the fertilisers.

The second trial used a high pH sandy soil, with varying moisture regimes. The N losses were distinctly higher on this soil (second trial) compared to the soils used in the first trial. With LAN, losses ranged from 1.58% and 1.62%. The moist soil scenarios had slightly lower losses for the all urea products compared to the dry soil. Losses were highest for product A (16.83%) and urea (16.21%) on the dry soil and for urea on the moist soil (13.68%). Product B was the best of the urea-based fertilisers, with losses of 11.61% on the dry soil and 9.2% on the moist soil regime. This represents a relative decrease of 26.7% on the dry soil and 32.3% on the wet soil compared to urea.

Table 1. Measured volatilisation losses in kg/ha and % of various N fertilisers in four different laboratory trials comparing various soil and management conditions.

	N loss (kg/ha)	N loss (%)	Cost per kg N after losses*	N loss (kg/ha)	N loss (%)	Cost per kg N after losses*
Trial 1	**Sandy loam (25% clay, pH 4.72)**			**Clay (38% clay, pH 7.16)**		
Control	0.13 (a)			0.39 (a)		
LAN	0.03 (a)	0.02	R14.82	0.94 (a)	0.58	R14.91
Urea	8.01 (c)	5.01	R10.99	8.94 (c)	5.58	R11.05
Product A	5.97 (b)	3.73	R13.16	5.41 (b)	3.38	R13.11
Product B	3.58 (b)	2.24	R11.61	2.86 (a)	1.79	R11.55
LSD (5%)	2.981			2.981		
Trial 2	**Sand, high pH (15% clay, pH 6.82) dry regime**			**Sand, high pH (15% clay, pH 6.82) moist regime**		
Control	0.14 (a)			0.17 (a)		
LAN	3.50 (a)	1.58	R14.84	2.59 (a)	1.62	R15.07
Urea	25.93 (bc)	16.21	R12.45	21.80 (b)	13.68	R12.09
Product A	26.92 (bc)	16.83	R15.23	18.60 (b)	11.63	R14.33
Product B	19.01 (b)	11.88	R12.88	14.75 (b)	9.22	R12.50
LSD (5%)	11.856			11.856		
Trial 3	**Sand (11% clay, pH 3.94) non-limed**			**Sand (11% clay, pH 4.87) limed**		
Control	0.50 (a)			0.34 (a)		
LAN	0.44 (a)	0.27	R14.86	3.29 (a)	2.06	R15.13
Urea	22.35 (e)	13.97	R12.13	49.20 (j)	31.22	R15.17
Product A	28.44 (f)	17.77	R15.44	32.22 (g)	20.14	R15.86
Product B	26.30 (ef)	16.44	R13.58	32.17 (g)	20.10	R14.20
LSD (5%)	5.124			5.124		
Trial 4	**Clay (41.5% clay, pH 5.22) bare**			**Clay (41.5% clay, pH 5.22) trashed**		
Control	0.11 (a)			0.07 (a)		
LAN	0.15 (a)	0.09	R14.83	0.07 (a)	0.35	R14.87
Urea	12.32 (b)	7.70	R11.31	26.31 (bc)	16.44	R12.49
Product A	8.88 (a)	5.55	R13.41	19.14 (b)	11.96	R14.39
Product B	6.98 (a)	4.36	R11.87	15.51 (b)	9.69	R12.57
LSD (5%)	11.27			11.27		

*Calculations based on December 2013 quoted product prices:
LAN = R4.15/kg, urea = R4.80/kg, Product A = R5.70/kg, Product B = R5.22/kg

The third trial investigated the influence of liming on volatilisation losses on low pH sand soil. The losses in the treatment without lime application are similar to those of the second trial. However this time urea showed slightly lower losses (13.97%) than product A (17.77%) and product B (16.44%).With lime application a drastic volatilisation increase to 31.22% of the applied N was measured for urea while the increase for Products A (20.14%) and B (20.10%) was smaller. In the limed scenarios the cost ranking is in favor of product B with LAN being the second cost effective product.

The fourth trial compared the volatilisation losses from the products on bare and trashed soil on low volatile clay soil. Losses were again lowest with LAN (0.09 to 0.35%). Losses for the urea-based fertilisers were more than doubled with a trash blanket as opposed to bare soil, and this applied to all three urea products. The losses ranged from 4.36% to 7.70% on the bare soil and from 9.96% to 16.44% on the trashed soil. In both scenarios product B showed again the best results. For the trashed scenario the relative decrease of losses compared to urea was 27.2% for product A and 41.1% for product B.

Conclusions

Under all conditions tested, volatilisation losses were significantly lower with LAN than with urea-based products. For the 'improved' urea products, compared with conventional urea, reduced volatilisation losses occurred on soils with low volatilisation risk (low pH loamy soils): Product A by 33.0% and Product B by 62.0%, which resulted in a comparable cost per unit N for Product B. On high volatilisation risk soils (sandy soils with high pH) Product A, did show losses comparable to urea while the performance of product B was slightly better with a relative decrease of losses of 29.5%.

After liming and under trashed conditions, where urea is generally not recommended, all urea products showed significantly increased volatilisation losses and cannot be recommended for such conditions. Comparing the costs after losses product B was in a competitive price range with urea.

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