SHORT COMMUNICATION

# Volatile losses of $NH_3$ from surface-applied urea and urea ammonium nitrate with and without the urease inhibitors NBPT or ammonium thiosulphate

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Grant, C. A., Jia, S., Brown, K. R. and Bailey, L. D. 1996. **Volatile losses of $NH_3$ from surface-applied urea and urea ammonium nitrate with and without the urease inhibitors NBPT or ammonium thiosulphate**. Can. J. Soil Sci. **76**: 417–419. Field microplot studies were conducted under zero-till conditions on a fine sandy loam (Orthic Black Chernozem) to determine the effect of the urease inhibitors N-(n-butyl) thiophosphoric triamide (NBPT) and ammonium thiosulphate (ATS) on volatile losses of $NH_3$ from urea and urea ammonium nitrate (UAN). Two studies were conducted, one in late May and one in early August. Losses of $NH_3$ were measured on days 1, 2, 4 and 7 after fertilizer application, using ammonia traps. Ammonia losses were higher in the second study, due to the higher soil temperatures and lower soil moisture later in the growing season. Total $NH_3$ losses increased in the order Control < UAN + NBPT = Urea + NBPT < UAN + ATS = UAN < Urea. Total loss of $NH_3$ during the 7 d after fertilizer application was higher from urea than from UAN, particularly in the first study. Use of NBPT was effective in reducing $NH_3$ volatilization from both UAN and urea during 7 d after fertilizer application while use of ATS had little influence on $NH_3$ loss from UAN. The NBPT may delay losses by slowing the hydrolysis of urea, but volatilization may persist for a longer duration. The delay in urea hydrolysis could allow time for rainfall to carry the urea into the soil, thus reducing total volatilization losses from surface fertilizer application.

**Key words:** N-(n-butyl) thiophosphoric triamide, zero tillage

Grant, C.A., Jia, S., Brown, K.R. et Bailey, L.D. 1996. **Pertes par volatilisation de $NH_3$ résultant de l'épandage en surface d'urée ou d'urée-nitrate d'ammonium avec ou sans les inhibiteurs d'uréase NBPT ou thiosulfate d'ammonium.** Can. J. Soil Sci. **76**: 417–419. Des essais en microparcelles réalisés au champ en régime de culture sans labour dans un loam sableux fin (chernozem noir orthique) avaient pour objet de déterminer les effets des inhibiteurs d'uréase, (N-butyl) triamide triophosphorique (NBPT) et du thiosulfate d'ammonium (TSA), sur les pertes par volatilisation de $NH_3$ à partir de l'urée et de l'urée-nitrate d'ammonium (UNA). Deux expériences étaient menées, l'une en fin mai, l'autre début août. Les déperditions de $NH_3$ étaient mesurées au moyen de piège à ammoniac, 1, 2, 4 et 7 j après l'épandage des engrais. Les déperditions d'ammoniac étaient plus fortes dans la seconde expérience, en raison de la température plus élevée et de la teneur en eau moins forte dans le sol à cette époque de l'eté. Les déperditions totales de $NH_3$ augmentaient dans l'ordre suivant: témoin < UNA + NBPT = urée + NBPT < UNA + TSA = UNA < urée. Les déperditions totales dans les 7 j suivant l'épandage des engrais étaient plus élevées à partir de l'urée seule que de l'association urée-nitrate d'ammonium, en particulier dans la première expérience. L'emploi du NBPT était efficace pour réduire la volatilisation de $NH_3$ à partir des deux engrais, dans les 7 j suivants l'épandage, tandis que le TSA n'avait que peu d'effets sur les déperditions de $NH_3$ à partir de l'association UNA. Bien que le NBPT puisse retarder les déperditions en freinant l'hydrolyse de l'urée, la volatilisation peut persister pour une plus longue durée de temps. Le ralentissement de l'hydrolyse de l'urée pourrait donner le temps à la pluie d'emporter l'urée dans la masse du sol, réduisant ainsi les pertes totales par volatilisation résultant de l'épandage en surface des engrais.

**Mots clés:** N-(n-butyl) triamide thiophosphorique, culture sans labour

Urea and UAN are N fertilizers used commonly on the Canadian prairies. Both urea and UAN are subject to N losses through volatilization of $NH_3$ when applied to the soil surface (Nelson 1982). Volatilization losses from urea or UAN can be reduced by in-soil banding or by incorporation of the fertilizer immediately after application. However, under a reduced tillage system, banding or incorporation leads to undesirable soil disturbance. Banding or incorporation of fertilizer also increases the cost of application as compared to an unincorporated surface application. Therefore, reduction of volatilization loss from surface application would be desirable, particularly under reduced tillage.

**Abbreviations: ATS**, ammonium thiosulphate; **NBPT**, N-(n-butyl) thiophosphoric triamide; **UAN**, urea ammonium nitrate

Urease inhibitors may be effective in slowing the hydrolysis of urea (Fairlie and Goos 1986; Christianson et al. 1990). Slowing urea hydrolysis would allow more time for urea to diffuse into the soil from the point of application. Diffusion of the urea away from the site of application combined with a reduced rate of formation of $NH_3$ and $NH_4^+$ would reduce the concentration of $NH_3$ and $NH_4^+$ present in the soil solution near the surface, thus reducing the potential for volatilization losses.

Both N-(n-butyl) thiophosphoric triamide (NBPT), also referred to as n-butyl phosphorothioic triamide (NBPT) (Bremner and Chai 1986; Schlegel et al. 1986; Christianson et al. 1990), and ATS (Fairlie and Goos 1986; Goos and Fairlie 1988; Sullivan and Havlin 1992) have been shown to act as urease inhibitors. However, little information is available comparing the effectiveness of ATS and NBPT in reducing volatile losses of N from fertilizers under field conditions, particularly on the Chernozemic soils of the Canadian prairies. This study was therefore conducted to compare volatile losses of N from urea with and without NBPT and UAN with and without NBPT or ATS, under field conditions on a Black Chernozemic soil.

Microplot experiments were conducted on a Marringhurst fine sandy loam soil (Orthic Chernozem, pH 7.3) which had been seeded to barley in the preceding year. The procedure was adapted from that described by Nommik (1973) and Fairlie and Goos (1986), with cylinder size, sampling periods and analytical procedures modified to compliment local conditions and facilities. Prior to the start of the experiment, wheat was direct-drilled into standing barley stubble. The stubble and the residue from the preceding crop were retained on the site. Two studies were conducted, the first beginning on 20 May and the second on 14 August 1995. The blocks where the two studies were conducted were 5 m apart. The first study was initiated 3 d after seeding, but before crop emergence. The second study was conducted after the wheat had headed. For the second study, wheat was mowed at a height of 4.0 cm and the fresh residue removed.

Polyvinyl chloride cylinders, 20 cm long and 15 cm in diameter, were arranged in a randomized complete block design, with three replicates and were pushed by hand 5 cm into the soil. The cylinders within a block were in two rows, with approximately 20 cm between each cylinder. The replicates were separated by approximately 50 cm. Filter paper was placed on the soil inside the cylinders and 150 mL of distilled water was poured over the paper to ensure equal moisture content of the soil. After 24 h, the filter paper was removed and fertilizer treatments were placed in a 2.0 cm circle on the soil surface in the centre of the cylinder, to simulate a surface dribble-banded application. The treatments were: 1) Control; 2) 100 kg N $ha^{-1}$ as urea; 3) 100 kg N as urea treated with 0.25% NBPT; 4) 100 kg N $ha^{-1}$ as UAN; 5) 100 kg N $ha^{-1}$ as UAN, treated with 0.25% NBPT; 6) 100 kg N $ha^{-1}$ as UAN and 10% ATS. The urea and urea treated with NBPT were in a granular form, while the UAN and UAN mixtures were in solution, reflecting the forms of the fertilizers that are utilized commercially.

After fertilizer application, each cylinder was fitted with two polyfoam disc ammonia sorbers, each 2.5 cm thick by 16 cm in diameter. The discs were prepared by washing and wringing out twice with distilled water, twice with 0.001 M $H_2SO_4$ and twice with a glycerol-phosphoric acid solution (100 mL 14.7 M $H_3PO_4$, 125 mL glycerol and 2275 mL water). The lower disc, for trapping the ammonia volatilized from the soil, was placed 5 cm above the soil surface, and the upper disc, for shielding the lower disc from atmospheric ammonia, was placed 5 cm below the top of the cylinder. The soft 16-cm diameter foam was compressed slightly to fit inside the 15-cm diameter cylinder, in order to ensure that no gaps existed between the foam and the cylinder. Clear plexiglass shields, supported at the corners by reinforcing bars, were placed 30 cm above the tops of the cylinders to protect the discs from rainfall, yet still allow free air movement. At 1, 2, 4 and 7 d after fertilizer application, the lower disc was replaced with a fresh disc and placed directly in plastic freezer bags containing 250 mL of 2 M KCl. The bags were immediately sealed and were air-tight. The disc was thoroughly rinsed with the KCl solution inside the sealed bags to extract the trapped ammonia. The solution was decanted into vials, sealed and frozen until analysis. Immediately after thawing, an aliquot of the solution was analyzed for ammonia concentration using a Technicon Autoanalyzer (Technicon Industrial Systems 1977).

**Table 1. Probability values from analysis of variance for log-transformed volatile loss of ammonia from two studies evaluating urea and UAN applications with and without NBPT or ATS**

| Source | Df | MSE | *F* value | *P* value |
|---|---|---|---|---|
| Study | 1 | 0.0721 | 293.1 | 0.0001 |
| Treatment | 5 | 0.2005 | 66.5 | 0.0001 |
| Treatment × study | 5 | 0.2005 | 4.3 | 0.0084 |
| Day | 3 | 0.0738 | 156.0 | 0.0001 |
| Study × day | 3 | 0.0738 | 8.8 | 0.0001 |
| Treatment × day | 15 | 0.0738 | 27.9 | 0.0001 |
| Study × treatment × day | 15 | 0.0738 | 4.5 | 0.0001 |

Statistical analysis was conducted using the general linear models procedure of the SAS Institute, Inc. (1985). As repeated measurements were conducted on the same plots over time, the data were analyzed as a repeated-measures design, with studies as the main plot units, treatments as the subplot units and days after application as the sub-subplot units. As a significant study × treatment × day interaction occurred, the data were also analyzed separately by study and day and means separation conducted using a Student-Newman-Keuls test. A logarithmic transformation was conducted on the data to equalize the variance across treatments (Steel and Torrie 1980).

Losses of ammonia were higher in the second study than in the first (Tables 1 and 2), presumably due to the higher soil and air temperatures and lower initial soil moisture levels in August as compared to May. Volatile losses of ammonia were lowest from the control, which received no N fertilizer. In the first study, losses during the first day after fertilizer application were highest from the UAN and the UAN plus ATS. The higher initial volatilization for UAN sources than from urea may have occurred because urea was provided as a granule and UAN as a solution. The granular source of N required dissolution of the granule before

**Table 2. Volatile losses of ammonia (mg N) from nitrogen fertilizer applications with and without NBPT or ATS**

| | Day 1 | | Day 2 | | Day 4 | | Day 7 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | Study 1 | Study 2 | Study 1 | Study 2 | Study 1 | Study 2 | Study 1 | Study 2 | Study 1 | Study 2 |
| Control | 0.00*a*[1] | 0.13*a* | 0.00*a* | 0.12*a* | 0.00*a* | 0.15*a* | 0.00*a* | 0.21*a* | 0.00*a* | 0.62*a* |
| Urea | 0.18*bc* | 1.21*bc* | 6.59*c* | 34.28*d* | 26.18*c* | 43.79*c* | 7.73*e* | 8.78*a* | 40.68*d* | 88.06*d* |
| Urea + NBPT | 0.00*a* | 0.20*ab* | 0.05*a* | 0.30*ab* | 0.23*a* | 3.05*ab* | 2.04*c* | 8.77*a* | 2.32*b* | 12.32*b* |
| UAN | 0.28*c* | 1.12*bc* | 0.52*b* | 2.27*c* | 1.28*b* | 15.26*b* | 5.04*de* | 31.17*b* | 7.12*c* | 49.81*c* |
| UAN + NBPT | 0.09*ab* | 0.65*ab* | 0.07*a* | 0.98*b* | 0.28*a* | 5.01*b* | 0.69*b* | 9.90*a* | 1.12*b* | 16.54*b* |
| UAN + ATS | 0.46*d* | 2.13*c* | 0.71*b* | 3.50*c* | 1.78*b* | 9.42*b* | 2.78*cd* | 10.93*a* | 5.72*c* | 25.99*bc* |
| MSE[z] | 0.0039 | 0.0531 | 0.0098 | 0.0477 | 0.479 | 0.3494 | 0.0773 | 0.2263 | 0.0682 | 0.1482 |

[z]MSE values calculated for transformed data.
*a-e*Numbers within a column followed by the same letter do not differ at the 5% probability level, using a Student-Newman-Keuls test for means separation on log transformed data.

volatilization commenced. Volatile losses of ammonia were high from the urea from day 2 to day 4, but declined substantially from day 4 to 7 after application. Rate of loss from the UAN and the UAN + ATS was lower than loss from urea from days 2 to 4. Losses of UAN from days 4 to 7 were similar to those from urea in the first study and higher than from urea in the second study. Cumulative losses of N from the urea treatment were approximately 38% of applied N in the first study and 83% of applied N in the second study. In both studies, cumulative loss over the 7-d period was in the order urea > UAN = UAN + ATS > UAN + NBPT = Urea + NBPT > control, indicating that NBPT was effective in reducing ammonia losses from both urea and UAN in the first 7 d after application. The trend towards higher losses from UAN + NBPT as compared to urea + NBPT may again reflect the requirement for dissolution of the granular urea fertilizer, which would be particularly evident under the drier conditions experienced in August. The NBPT was less effective at reducing ammonia loss in the second study than in the first probably due to the higher soil temperatures in August. Carmona et al. (1990) reported a decline in relative efficiency of NBPT with increasing temperatures.

The ATS was ineffective in reducing ammonia loss from UAN in the first study, and was less effective than NBPT in the second study. Although Goos and Fairlie (1988) indicated that ATS acted as a urease inhibitor, Sullivan and Havlin (1992) reported that thiosulphate was a relatively weak urease inhibitor and that crop response to ATS as a urease inhibitor would probably be too small to detect consistently in the field through measurements of yield or N uptake.

The urease inhibitor NBPT was effective in reducing volatile losses of ammonia from UAN and urea during the first 7 d after application. Loss of ammonia from the urea peaked at 4 d and then declined from day 4 to day 7. In contrast, losses from the urea + NBPT and UAN + NBPT were highest from day 4 to day 7. This indicates that NBPT may delay losses, by slowing the hydrolysis of urea, but volatilization may persist for a longer duration. The use of rain shelters in this experiment would have precluded movement of the urea into the soil with rainfall. In a natural situation, delaying volatile losses of ammonia could allow a longer time for rainfall to move the urea into the soil, therefore potentially reducing total volatilization losses.

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