

The potential for inhibitor coated nitrogen fertilisers to reduce agricultural fertiliser N losses

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Abstract

Agriculture is a major source of the potent greenhouse gas nitrous oxide (N₂O) (contributing 75% to the national total). Ammonia (NH₃) volatilisation is not only one of the main causes of low efficiency of N fertiliser, with reported losses of up to 48%, but also an indirect greenhouse gas (Chen *et al.* 2008). Fertilisers coated with urease or nitrification inhibitors have shown promise in reducing these losses from applied N, but the effectiveness of these stabilised fertilisers in the field is influenced by environmental and edaphic factors. Information on how the different inhibitor coated fertilisers perform in different soils and agro-ecological regions is required for development of best management practice.

This paper provides a summary of extensive laboratory studies on urease and nitrification inhibitors and identifies the main drivers influencing the performance of these inhibitors in a range of soils. The urease inhibitor *N*-(*n*-butyl) thiophosphoric triamide, (NBPT) delayed complete hydrolysis of urea by between 2 and more than 14 days compared to urea, and soil urease activity was identified as a key driver of performance. In the field NH₃ volatilisation reductions of around 68% were achieved with NBPT compared to normal urea in pastures. The nitrification inhibitors dicyandiamide (DCD), 3,4-dimethylpyrazole phosphate (DMPP) and Nitrapyrin (N-serve) reduced N₂O emissions by between 15 and 98%, but the reasons for this range of responses are unclear. N-serve and DMPP performed equally at 15°C and N-serve performed better at 25°C in the soils tested. DCD and DMPP performed equally well under cooler conditions (5, 15, 25°C) and DMPP performed better than DCD at high temperatures (35°C).

Key Words

DCD; DMPP; N-serve

Introduction

Application of nitrogen (N) fertiliser is necessary for agricultural production to feed a growing population, yet the efficiency of applied N is considered low, with 6-60% of applied N taken up by plants in Australian agricultural crops (Chen *et al.* 2008). Various management practices can be used to reduce N losses from agriculture including rate, timing and method of application of the fertiliser, and choice of product. The choice of products includes different forms of N, liquid or solids, granule size and products that are coated with controlled or slow release coatings or with urease and nitrification inhibitors.

Urea is a commonly used N fertiliser but is subject to loss via ammonia (NH₃) volatilisation when surface applied because the hydrolysis of urea, catalysed by the urease enzyme, can be rapid and cause localised elevated pH around the urea granule. The amount of NH₃ loss depends upon many external factors such as soil pH, urease activity, climatic conditions (rainfall, temperature, wind speed) and can range from no loss to up to 48% of applied N (Cai *et al.* 2002). High losses of NH₃ have been measured under high urease activity (organic) environments where urea hydrolysis is rapid, or on alkaline soils. Urease inhibitors suppress the activity of the urease enzyme and slow the rate of urea hydrolysis, reducing the risk of NH₃ loss by reducing the localised elevated pH. The impact of ureases inhibitors is variable across soils and climatic conditions.

Ammonium in soil, from mineralisation or fertiliser application, undergoes nitrification producing leachable nitrate (NO₃⁻). Nitrous oxide (N₂O) is also produced either from denitrification of NO₃⁻ or as a leakage in the nitrification process. Nitrification inhibitors suppress the activity of the bacteria involved in nitrification and hence slow nitrification, which can reduce the production of leachable NO₃⁻ and associated N₂O emissions. Reduction in NO₃⁻ and N₂O formation with nitrification inhibitors is variable across soil type, climatic conditions and inhibitor (Merino *et al.* 2005; Di *et al.* 2007).

This paper provides a summary of results from both laboratory and field experiments on the performance of urease and nitrification inhibitors.

Methods

Laboratory incubation experiments were carried out using airdried soil (< 2 mm) collected from various

locations and agricultural industries in eastern Australia to assess the impact of climate and soil properties on the performance of the inhibitors. The soil was wetted to a moisture content of 60 or 85% water filled pore space (WFPS) and incubated at constant temperature ranging from 5 to 35°C after treatments were applied. Nitrogen was surface applied as granular urea to test the urease inhibitor (N-(n-butyl) thiophosphoric triamide (NBPT) at a rate of 0.1 w/w urea) at a rate of 100-160 kg N/ha (4-5 granules), and measurements were taken for 21 days. In the nitrification experiments N was applied as urea or ammonium sulphate at rates of 250 to 1150 mg N/kg soil and the experiments ran for 70 days.

A field trial was conducted on a ryegrass seed crop where urea was applied alone or with urease or nitrification inhibitors, at a rate of 40 kg N/ha (recommended application rate) over an 8 month period. Ammonia loss was measured in two 4 week campaigns using micrometeorological techniques, and N₂O (manual chambers) and soil mineral N were measured at regular intervals.

Results

Urease inhibitors

The application of urease inhibitors slowed the hydrolysis of urea. In a wheat cropping soil (urease activity 90 µg urea N/g soil/hr, organic C 1.3%) urea hydrolysis at 5, 15 and 25°C was completed within 5, 7 and 10 days for urea and 14 (25°C) and more than 14 (5, 15°C) days for urea with NBPT. In a pasture soil (urease activity 186 µg urea N/g soil/hr, organic C 11% (including pasture thatch)) hydrolysis was much more rapid and completed within 3-5 days at all temperatures. Addition of NBPT increased the time for complete hydrolysis of urea to 7 (15 and 25°C) and 14 days (5°C) (Suter *et al.* 2011). Urease activity was a major factor influencing the ability of the urease inhibitor to retain urea. In the field application of the urease inhibitor NBPT reduced NH₃ loss from granular urea applied to a ryegrass seed crop from 30% to 9% of applied N in an autumn experiment and from 2 to 1% in a spring experiment where rain fell within 24 hours of N application. The results highlight the importance of climatic factors on the performance of the inhibitor.

Nitrification inhibitors

There was a wide range of responses to the application of nitrification inhibitors with urea or ammonium sulphate across a range of soil types. No clear factor was identified as being the major driver of performance of any inhibitors across the soils tested. For example, results from two Queensland sugarcane soils (clay, pH_w 5.3; clay loam, pH_w 4.8) showed the inhibitor (DMPP) performed extremely well in the clay soil, reducing both NO₃⁻ production and N₂O emissions by > 85% at 25 and 35°C, whilst in the clay loam the inhibitor had less impact on NO₃⁻ formation and reduced N₂O emissions by 19% (35°C) to 64% (25°C). In a clay soil from Victoria (pH_w 8.3) the inhibitors DMPP and N-serve performed equally well at 5 and 15°C, but N-serve was better at 25°C. (Chen *et al.* 2010). The ability of the inhibitors to reduce nitrification was found to depend on temperature (less effective at higher temperature), but the impact of temperature was dependent on the inhibitor with performance at higher temperature following the order N-serve ≥ DMPP > DCD, and also soil properties with greater inhibition at higher pH.

Conclusions

Urease and nitrification inhibitors have the ability to reduce N losses from applied N fertilisers in Australian agriculture. They do not perform to the same degree under all situations and so their application should be targeted at soils, agricultural industries and seasons where the greatest benefit is likely to be seen. Factors driving the variability of inhibitors to reduce fertiliser N losses require further investigation.

References

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