Abatement Options for Nitrogen Fertiliser

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Introduction

The introduction of nitrogen (N) fertiliser over the past 50 years has been one of the great success stories, allowing dramatic increases in agricultural productivity world-wide. However, with more than 1 billion tonnes of N per year used globally, there are now serious environmental concerns from ammonia (NH$_3$) volatilisation, nitrate (NO$_3$) leaching and nitrous oxide gas emissions. Nitrous oxide (N$_2$O) has become the third most important greenhouse gas after carbon dioxide and methane, with a global warming potential around 300 times that of carbon dioxide, while also contributing to stratospheric ozone depletion (Smith et al. 2007).

Extensive research has been conducted and reported world-wide on the management of N fertilisers, both focused on maximising their efficiency in terms of crop and pasture production, but also reporting on best practices to minimise N losses to the environment. In spite of this, between 30% and 60% of the N inputs into crop and pasture systems can be lost to the environment (Whitehead 1995). There is thus still much room for improvement and reducing these losses further.

It is clear that globally and in Australia we are facing an increasingly emissions constrained future and policy measures will be introduced to drive emission reductions, through placing a price on carbon and/or establishing offset trading schemes. The latter could provide significant opportunities for the fertiliser industry.

Sources of N loss

According to the Australian national greenhouse gas inventory (NGGI) (DCC 2009), the agricultural sector produced an estimated 88.1 Mt CO$_2$-e emissions or 16.3 per cent of national inventory emissions in 2007. Agriculture was the dominant national source of both methane (CH$_4$) and N$_2$O, accounting for 67.9 Mt CO$_2$-e (58.9%) and 20.2 Mt CO$_2$-e (85.9%) respectively of the net national emissions for these two gases. Enteric methane is the largest single source of emissions, contributing 65.3% of agricultural emissions (9.6% of national emissions), with nitrous oxide from soils contributing 17% (2.5% of national emissions).

Direct emissions of N$_2$O from fertiliser used makes up 3.1% of agricultural emissions (19% of total N$_2$O emissions from agriculture, Figure 1), while N$_2$O from indirect sources makes up 7% of agricultural emissions (41% of total N$_2$O). These indirect emissions assume that some of the NH$_3$ volatilised and the NO$_3$ leached becomes N$_2$O in subsequent off-site processes and thus contributes further to total N$_2$O emissions.

Thus it is imperative that we focus our efforts not just on reducing denitrification as the sole source of N$_2$O, but also on management that minimises NH$_3$ volatilisation and NO$_3$ leaching. The only ‘safe’ loss of N, from an environmental perspective, is complete denitrification where predominantly N$_2$ is formed under saturated soil conditions.
Abatement options

The rate, source and timing of N fertiliser applications are important management factors affecting the efficiency of crop and pasture growth responses, and thus potential N₂O losses.

Matching the rate of N fertiliser to the potential crop or pasture demand is critical to ensuring both high efficiency of N use, but also minimising potential N losses. This involves a combination of the timing (stage of growth/regrowth, season/temperature, soil conditions) in combination with the rate to be applied, to ensure maxim plant uptake, but avoiding applications in excess of immediate requirements.

Graphs similar to those in Figure 2 have been well understood for a number of years now, showing exponentially increasing N loss potential (N₂O in this case) as N fertiliser inputs exceed the soil-plant-systems capacity to utilise the applied N. When conditions are suitable for denitrification, N₂O emissions increase exponentially with the rate of N applied in any single application (de Klein and Eckard 2008; Eckard et al. 2009; Eckard et al. 2006a; Mosier et al. 1983; Whitehead 1995).

Current precision agriculture methods (eg. geographic information technology, variable-rate technology, soil nitrate tests, computer modelling) and careful attention to current best practice can ensure that the rate, timing and placement of N fertiliser optimise nitrogen use efficiency.

Figure 1. Sources of N₂O losses in the 2007 National Greenhouse Gas Inventory (DCC 2009).
Figure 2. The annual pasture DM response, from a modelled perennial ryegrass-based pasture in Victoria, and consequent losses of N from increasing rates of N fertiliser applied (Eckard et al. 2006b).

Nitrate-based N fertiliser has been shown to result in high N$_2$O emissions and higher NO$_3$ leaching, relative to ammoniated-N sources, when applied to actively growing crops or pastures, particularly under wetter soil conditions conducive to growth (de Klein and Eckard 2008; Eckard et al. 2009).

However, with the recent inclusion of indirect N$_2$O in the IPCC and National Greenhouse Gas Inventory, NH$_3$ volatilisation has now also become a focus of attention. Unfortunately, products like urea fertiliser, while losing less direct N$_2$O through denitrification and less NO$_3$ through leaching, have been show to lose far more NH$_3$ through volatilisation, but only when applied during hot, windy and highly evaporative conditions (Eckard et al. 2003). Strategies like incorporation, timing with weather or irrigation and applying 2 to 3 days before grazing can all reduce the NH$_3$ volatilised. Urease inhibitor-coated fertiliser products are also readily available for situations where high NH$_3$ loss from urea may be otherwise unavoidable. These products do increase the unit cost of the N fertiliser and the producer will need weigh the costs against the likely reduction in N loss.

Nitrification inhibitors are chemical compounds that inhibit the oxidation of NH$_4^+$ to NO$_3^-$ in soils and thus reduce N$_2$O emissions from NH$_4^+$-based fertilisers or from urine (Di and Cameron 2002). Nitrification inhibitor-coated fertilisers have been shown to be effective in reducing nitrification, NO$_3$ leaching, and N$_2$O emissions by up to ~80% (de Klein and Eckard 2008; de Klein et al. 2001). Applied as a spray, nitrification inhibitors can also be effective in reducing N$_2$O emissions from animal urine by 61–91%, with pasture yield increases of 0–36% (Di et al. 2007; Kelly et al. 2008; Smith et al. 2008). Nitrification inhibitor coated fertilisers are likely to become more commonplace with an increasingly emissions-constrained future.
Controlled Release Fertilisers are usually prills of fertiliser encapsulated in a polymer or oil-based coating. The polymer coating controls the rate of release by allowing the fertiliser to pass through the coating often controlled by the thickness or type of polymer used and soil conditions (often referred to as biodegradable resin-coated slow-release fertilisers, or methylene-urea polymers). Slow Release Fertilisers work by changing the chemical composition or mixing the fertiliser to reducing its solubility. The key difference between these two technologies may appear semantics, but are used strongly in marketing in that one product actual controls the release pattern and timing, while the other is merely a constant, but slower release of the nutrient.

Conclusions

By careful management of the rate, source, timing and placement of N fertilisers, we can reduce unnecessary losses from fertiliser use. However, there is likely to be an increasing pressure to further reduce N losses as we move into an increasingly emissions constrained future.

Nitrification and urease inhibitors and slow or controlled release fertilisers are thus likely to see an increasing market share into the future in an effort to improve N use efficiency and reduce losses to the environment. Likewise, best practices for managing the rate, source, timing and placement of N fertiliser will require more attention in future.

There is also market scope for the development of more innovative sources of N that can meet plant requirements while minimising N losses, allowing agricultural production to continue to meet increasing global demand as we enter an increasing emissions constrained world. The fertiliser industry can therefore play a proactive role in this emissions constrained future, capturing new revenue from emissions or offset trading in lower emissions N products.

References


