Nitrous oxide emissions in the Sugar Cane Industry

Less than 30 per cent of N inputs fertliser losses from denitrification, organisms, such as bacteria and fungi, plants take up ammonium and nitrate, N supply from soil organic matter needs denitrifying bacteria complete the N pathway. There is considerable scope to nitrifying bacteria convert ammonium N-fixing bacteria convert N gas. The amount of N fertiliser applied to dairy pastures can be lost into the atmosphere as nitrogen gases, such as nitrous oxide, following heavy summer rain. The cycling of N gas from the atmosphere through soil microbes, plants, animals and manufactured fertilisers is known as the N cycle. Keeping this cycle in balance is the key to minimising losses of plant-available N into the atmosphere and waterways (or beyond plant roots) via leaching.

Nitrogen cycle processes:
- N-fixing bacteria convert N₂ into ammonium (NH₄⁺);
- nitrifying bacteria convert ammonium into nitrite (NO₂⁻), and then into nitrate (NO₃⁻);
- plants take up ammonium and nitrate, and convert it into plant tissue, which is then consumed by animals;
- organisms, such as bacteria and fungi, convert animal excrement and dead animal and plant tissue to ammonium, which then also goes through the nitrifying process above; and
- denitrifying bacteria complete the N cycle by converting nitrate back to gaseous nitrogen compounds (N₂, N₂O and NO).

N₂ is the main form of gas produced from denitrification when soil microbes convert nitrate into N gas. The ratio of N₂ to N₂O is usually about 50:1 in a typical season, but this ratio varies depending on soil pH and moisture content.

THE NITROGEN CYCLE

While nearly 80 per cent of our atmosphere is N, most living organisms cannot access this gaseous N pool until it has been ‘fixed’ into an inorganic, reactive form that plants can use. There are two main ways that dinitrogen gas (N₂) is fixed into an inorganic form, as mineral N. The first is a biological process via N-fixing bacteria in the soil; the second is an industrial process that converts N gas into N fertilisers. A small amount is also fixed via lightning strikes.

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Soils do not need to be noticeably waterlogged to stimulate denitrification. When waterlogged soil (low in oxygen pockets), high soil nitrate and high soil organic matter occur simultaneously then denitrification can be significant. Up to 45 per cent of applied N was found to be lost as gaseous N emissions following a large storm event.

**N₂O AND THE DAIRY INDUSTRY**

Less than 30 per cent of N inputs into dairy farming systems are accounted for in milk production – the unaccounted-for balance showing there is considerable scope to improve N use efficiency (NUE) and reduce N fertiliser inputs.

Dairy pasture soils generally have high organic carbon content of three to six per cent compared with other Australian agricultural soils. As a consequence, there is considerable potential for applied N fertiliser to escape into the atmosphere as N gases, such as N₂O and N₂, particularly in wet and saturated soil conditions.

*N fertiliser losses as N₂O emissions can be reduced in the dairy industry by:*

- better matching N fertiliser supply to a pasture’s N demand;
- reducing N fertiliser rates by taking into account the amount of soil N mineralised from soil organic matter; and
- use of enhanced efficiency fertilisers (EEFs) to slow the production of nitrate in the soil.

**FATE OF APPLIED NITROGEN**

Research in Gympie, Queensland, examined the uptake of applied N fertiliser in irrigated dairy pastures. In these trials, average annual rainfall for the area was 1133 millimetres, predominantly in summer. The soil was clay-loam with a total organic carbon content of 4.7 per cent and a pH of 6.

The research showed that up to 40 per cent (125kg N/ha) of N fertiliser applied to dairy pastures was lost, principally from denitrification (mostly N₂, but also N₂O), following large summer rain events. A relatively small amount of N fertiliser – less than nine per cent – was also lost in run-off. Leaching losses were negligible. While these N losses had a low environmental impact, the effect on profitability (based on urea priced at $600 per tonne) was more than $150/ha per year.

High denitrification activity identified in the Gympie soils was attributed to their high soil organic carbon content, which provided a significant source of nitrate for soil microbes to convert into N gases such as N₂O.

**SOIL ORGANIC MATTER**

The Gympie research also found that only about 30 to 40 per cent of N uptake by dairy pastures had come from N fertiliser, with the remaining 60 to 70 per cent (140kg N/ha) derived from soil organic matter.

Long-term applications of N at high rates, plus additional N inputs from cow manure and urine at the trial site, had created a large reserve of organic N in the top 30 centimetres of the soil profile (more than 10,000kg N/ha).

The research highlights that N from soil organic matter can make a significant contribution to pasture productivity, which needs to be considered when developing N fertiliser management strategies that aim to improve NUE and profit margins.

**N₂O ‘HOT SPOTS’**

Research at Gympie found that more than a third of total N₂O emissions from a dairy farm came from laneways and cattle camps used by 200 to 240 milking cows. Annual losses from these high-traffic sites, which represented just three per cent of the total farm area, were 115kg N/ha.

Emissions from N₂O ‘hot spots’ can be reduced by regularly moving feed troughs around the grazed pasture area to decrease the N concentration from urine and manure deposits and reduce the soil compaction that promotes denitrification.

Although dairy pastures generally produce low N₂O emissions per hectare, they contribute the most greenhouse gas emissions (predominantly as N₂O) compared with other agricultural farming systems, due to their relatively large area, highlighting the need for N₂O mitigation strategies in dairy farming.

**N₂O AT HOT TEMPERATURES**

Research in New South Wales examined N₂O emissions from clay-loam soil on a dairy farm with 650mm average annual rainfall and organic soil carbon content of 2.9 per cent in the top 10cm of the soil profile. This research showed that doubling N fertiliser rates typically used in the NSW dairy industry substantially increased pastoral productivity and had a relatively low effect on N₂O emissions.

**NITRIFICATION INHIBITORS**

In dairy pastures where moderate to high N fertiliser rates were used, EEFs or nitrification inhibitors can slow the conversion of ammonium to nitrate, which slows the conversion of nitrate to N₂O.

Other EEFs are urease inhibitors, which delay the hydrolysis of urea into ammonium, and polymer-coated fertilisers, which slowly release N in the soil.

A nitrification inhibitor, 3,4-dimethylpyrazole phosphate (DMPP), is typically used as a coating on urea fertiliser applied to Australian dairy soils.

When applied on urea during winter months at reduced N fertiliser rates, DMPP reduced both N₂O losses from a subtropical intensive dairy farm by 42 per cent and total N losses by 80kg/ha, providing an N fertiliser cost saving of more than $150/ha a year.

However, in NSW research looking at the influence of hot temperatures in free-draining soils, applications of DMPP-coated urea did not reduce N₂O emissions, lift pasture productivity or provide environmental benefits.

**MORE INFORMATION:**

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**Grains Research 
and Development Corporation**

**Australian Government**

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