NANORP FERTCARE®

National Agricultural Nitrous Oxide Research Program

DAIRY INDUSTRY FACT SHEET

Nitrous oxide emissions in the Dairy Industry

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PHOTO: CATHY PHELPS, DAIRY AUSTRALIA

Up to 40 per cent of nitrogen fertiliser applied to dairy pastures can be lost into the atmosphere as nitrogen gases, such as nitrous oxide, following heavy summer rain.

KEY POINTS

- There is considerable scope to improve nitrogen (N) use efficiency in dairy farming systems.
- Less than 30 per cent of N inputs are recovered in milk production in intensive dairy systems where soils receive fertiliser applications of up to 350 kilograms of N per hectare.
- N supply from soil organic matter needs to be taken into account when developing fertiliser management strategies.
- N fertiliser losses from denitrification (dinitrogen gas and nitrous oxide) can be significant (up to 40 per cent of applied N) from waterlogged soils and from 'hot spots', such as high-traffic cattle areas.
- Nitrification inhibitors can, in some circumstances, mitigate nitrous oxide emissions, but they were only found to lift pasture productivity on subtropical dairy soils

Agriculture is responsible for an estimated 85 per cent of Australia's emissions of nitrous oxide (N_2O), a greenhouse gas with almost 300 times the potency of carbon dioxide.

N_2O emissions represent inefficiency in fertiliser use and lowering the amount of this nitrogen (N) gas lost from the soil could generate on-farm cost savings.

The amount of N_2O emitted when N fertiliser escapes into the atmosphere varies between farming systems, soil types, climates and farm management practices, which means there is no single solution to reducing emissions.

N losses as N_2O emissions from Australian agricultural systems vary from about 10 grams of N per hectare from no-till cereal crops receiving 100 kilograms of N/ha in low-rainfall areas of Western Australia to nearly 15.5kg nitrous oxide-nitrogen (N_2O-N)/ha from sugarcane receiving 140kg N/ha in northern Queensland.

This fact sheet highlights research during round one of the National Agricultural Nitrous Oxide Research Program (NANORP), from June 2012 to June 2015, which aimed to quantify N_2O emissions and develop ways to drive down emissions across five of Australia's agricultural industries: grains, sugarcane, cotton, horticulture and dairy.

Fertcare® is a joint initiative of Fertilizer Australia and the Australian Fertiliser Services Association. Fertcare® supports the objective of decreasing N_2O emissions through best practice in fertiliser supply, advice and contract application. A key component of Fertcare® is dissemination of information so that N fertiliser decisions can be made based on facts and scientific findings.

NITROGEN USE EFFICIENCY

NANORP research shows that, on average, 40 per cent of applied nitrogen fertiliser is permanently lost from Australian agricultural soils via leaching, run-off and as N gas. This equates to an estimated $400 million loss of fertiliser per year, plus a significant environmental risk to waterways and contribution to global warming.

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 (N_2) 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.

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 N_2 into ammonium (NH_4^+);
- nitrifying bacteria convert ammonium into nitrite (NO_2^-), and then into nitrate (NO_3^-);
- 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 (N_2, N_2O and NO).

N_2 is the main form of gas produced from denitrification when soil microbes convert nitrate into N gases. The ratio of N_2 to N_2O is usually about 50:1 in a typical season, but this ratio varies depending on soil pH and moisture content.

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.

N_2O 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 N_2O and N_2, particularly in wet and saturated soil conditions.

N fertiliser losses as N_2O 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 N_2 but also N_2O), 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 N_2O.

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.

N_2O 'HOT SPOTS'

Research at Gympie found that more than a third of total N_2O 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 N_2O '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 N_2O emissions per hectare, they contribute the most greenhouse gas emissions (predominantly as N_2O) compared with other agricultural farming systems, due to their relatively large area, highlighting the need for N_2O mitigation strategies in dairy farming.

N_2O AT HOT TEMPERATURES

Research in New South Wales examined N_2O 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 pasture productivity and had a relatively low effect on N_2O 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 N_2O.

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 N_2O 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 N_2O emissions, lift pasture productivity or provide environmental benefits.

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