NANORP

National Agricultural Nitrous Oxide Research Program

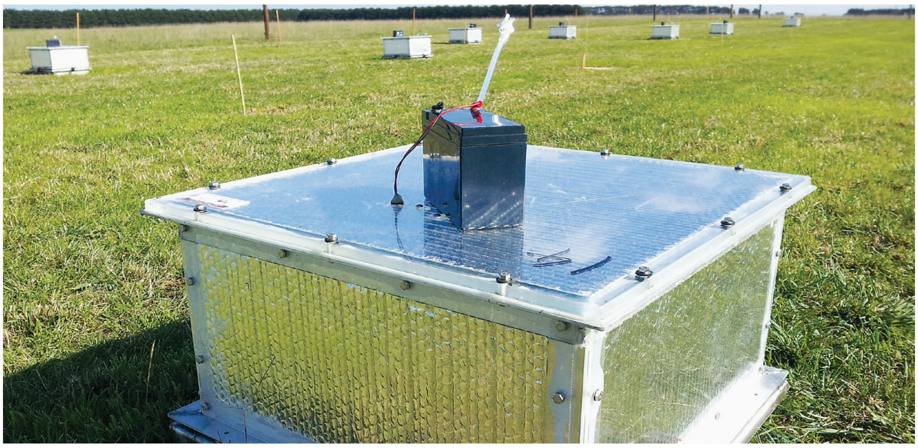
DAIRY INDUSTRY FACT SHEET

Nitrous oxide emissions in the Dairy Industry

MARCH 2016

Nitrogen (N) is vital for dairy pasture growth, yet up to 40 per cent of N fertiliser applied in dairy farming systems can be lost into the atmosphere as nitrous oxide (N_2O), a greenhouse gas about 300 times more potent than carbon dioxide. Maximising N availability using on-farm practices that improve N use efficiency can help lift productivity and profitability and reduce N_2O emissions in dairy farming systems.

PHOTO: DR HELEN SUTER, UNIVERSITY OF MELBOURNE



A chamber used to measure nitrogen fertiliser losses as nitrous oxide at a dairy trial site in South Australia.

KEY POINTS

- Saturated, acidic soils with high soil organic content are the most prone to nitrous oxide (N_2O) emissions.
- Up to 40 per cent or 125 kilograms of nitrogen (N) per hectare can be lost from dairy pastures on soils with high organic carbon content following heavy summer rain.
- Applying N fertiliser more frequently at low rates before irrigating pasture can help reduce N input losses by up to 80 per cent.
- Only 30 to 40 per cent of a dairy pasture's N supply comes from applied fertiliser. The majority is sourced from soil organic matter.
- More than 30 per cent of N_2O emissions can come from high-traffic areas, such as laneways and cattle camps, which comprise about three per cent of a farm's total area.
- In a subtropical climate, the nitrification inhibitor 3,4-dimethylpyrazole phosphate reduced N_2O emissions by 42 per cent. However, it did not reduce emissions in a temperate climate with free-draining soils.

FERTILISER 'EMISSIONS'

Nitrogenous fertiliser is a major, consistent investment in dairy pasture growth that Australian farmers make in order to meet milk production targets.

However, research under the National Agricultural Nitrous Oxide Research Program (NANORP) has found a high proportion of nitrogen (N) fertiliser applications are lost as nitrous oxide (N_2O).

Over a 100-year period, N_2O has up to 310 times more potency than carbon dioxide and it is the fourth largest contributor to greenhouse gas emissions.

For example, N_2O emissions from dairy pasture measured on a property in south-east Queensland were more than one kilogram of N per hectare per day.

But NANORP research has also shown that improving N use efficiency (NUE) – with a focus on reducing N losses as N_2O – can provide both economic and environmental benefits for dairy farmers.

This fact sheet highlights research relating to the dairy industry completed during round one of NANORP, which ran from June 2012 to June 2015.

The nitrogen cycle

The process in which N is converted into various chemical forms is called the N cycle. N is present in the soil in two major forms:

- inorganic, as mineral N; and
- organic, such as soil organic matter, soil microorganisms and plant residues.

Organic N typically accounts for more than 90 per cent of all N in soil, but it is usually not directly available to plants. It must first be converted to soluable inorganic forms, such as ammonium or nitrate, before it can be used by plants.

Denitrification is the conversion, by soil microbes, of nitrate into N gases, including N_2O, nitric oxide and dinitrogen (N_2). N_2 is the main form of N gas lost into the atmosphere, although the proportion of each N gas produced depends on soil pH and moisture content.

The microbes that convert nitrate into N gases need oxygen for metabolism. Under waterlogged conditions, where oxygen is limited, they obtain oxygen from nitrate molecules. This results in the production of gaseous oxides and N_2 gas.

NANORP research has confirmed denitrification is the principal source of N_2O emissions from Australian agricultural soils. Denitrification occurs more readily in waterlogged soils, which means more soil N is lost as N_2O in high-rainfall areas than in dry areas.

For dairy farmers, mitigating the denitrification process is important in terms of on-farm productivity and profitability.

NITROGEN AND YIELD

N is an essential macronutrient for dairy pasture growth. High-yielding pasture, as part of a productive dairy operation, requires a significant supply of plant-available N. The N required by dairy pasture can come from fertiliser applications, mineralisation of soil organic matter and N-fixing legumes. N fertiliser is typically applied as urea and ammonium phosphates in the dairy industry. Major sources of N in soil organic matter are organic fertilisers such as urine, dung and effluent, plus residues derived from plant litter on grazed pasture and supplementary feed for dairy cows.

NUE AND YIELD

NUE is a measure of how effectively N is taken up by plants for pasture growth.

Improving NUE increases the pasture yield achievable per unit of fertiliser applied because more N is available to the plant and not lost into the atmosphere as gas.

However, N_2O emissions are closely linked to total denitrification losses, which can result in the loss of up to 40 per cent of N fertiliser applications.

As a consequence of this link, increasing NUE by reducing N losses from denitrification has the potential to reduce N_2O emissions and provide cost-benefits for dairy farmers.

Denitrification remains a challenge, however, because dairy farms are most prevalent in high-rainfall costal zones where soils are prone to saturation, increasing the risk of N losses as N_2O. Inland irrigated dairy farms in southern New South Wales, northern Victoria and the Murray–Darling Basin area of south-east Australia are also susceptible to high N_2O emissions due to waterlogging.

ON-FARM PRACTICES TO BOOST NUE

Fertiliser management

NANORP research generally showed that wet, acid soils with high soil organic content are the most prone to N_2O emissions.

Trials in NSW on a temperate dairy farm with clay-loam soils and average annual rainfall of 650 millimetres showed pasture yields were limited by the relatively low N fertiliser rates typically used in that state.

The research, led by Dr Warwick Dougherty from the NSW Department of Primary Industries, showed that doubling the conventional N fertiliser rate significantly boosted pasture productivity without substantially increasing N_2O emissions.

Dr Dougherty says that applying N fertiliser more frequently at low rates before irrigating pasture could help optimise NUE by reducing applied N losses by up to 80 per cent.

Great nitrogen escape

Trials in Queensland on a subtropical dairy farm with clay-loam soils, high average annual rainfall of 1133mm and high soil organic carbon content found up to 40 per cent (or 125kg/ha) of applied N fertiliser was lost as N gases.

Leading this research, Queensland University of Technology's Dr David Rowlings says the N fertiliser losses, mostly as N_2 but also as N_2O, followed large summer rain events.

Dr Rowlings says that while the gaseous N losses had a relatively low environmental impact, they had an annual cost of more than $150/ha based on a urea price of $600 per tonne.

High denitrification activity at this site was largely attributed to the soil's high organic carbon content.

Organic content matters

Dr Rowlings says the research also found that only 30 to 40 per cent of dairy pastures' N uptake had come from applied N fertiliser. The majority of N taken up by pasture – 60 to 70 per cent – was sourced from soil organic matter.

N from cow manure and urine, plus long-term fertiliser applications, had combined to provide a soil organic N reserve of more than 10,000kg/ha in the top 30 centimetres of the soil at the experimental site.

This highlighted the importance of assessing the soil's organic N content as part of fertiliser strategies to lift NUE and profit margins in dairy farming systems.

Traffic and N_2O

Dr Rowlings's research found that more than 30 per cent of total N_2O emissions came from laneways and cattle camps (used by 200 to 240 cows), which comprised just three per cent of the dairy farm area.

Annual losses of 115kg N/ha measured on such high-traffic sites can be reduced by regularly relocating feed troughs on grazed areas. This practice decreases high N concentrations in the soil from manure and urine deposits and mitigates soil compaction, which both promote denitrification.

Nitrogen inhibitors

NANORP research also explored the potential for enhanced efficiency fertilisers (EEFs) to increase pasture yields and reduce N_2O emissions from dairy soils.

The EEF or nitrification inhibitor 3,4-dimethylpyrazole phosphate (DMPP), used as a coating on urea applied at low rates during winter, was found to reduce N_2O emissions by 42 per cent and decrease applied N losses by 80kg N/ha in a subtropical farming system.

But in a temperate farming system, with free-draining soils less prone to saturation, DMPP-coated urea did not reduce N_2O emissions or increase pasture productivity.

Slow-release fertiliser

Ongoing research by the University of Newcastle's Professor Scott Donne aims to develop a slow-release N fertiliser from activated charcoal that can supply N for plants and lower gaseous N losses from the soil.

Preliminary studies have shown this fertiliser has the potential to increase pasture yield and mitigate N_2O emissions by better controlling the release of soil N for plant uptake.

MORE INFORMATION:

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