NANORP
National Agricultural Nitrous Oxide Research Program

GRAINS INDUSTRY FACT SHEET

MARCH 2016

Nitrous oxide emissions in the Grains Industry

Nitrogen (N) is vital for crop growth, yet up to 600 grams of N per hectare per day 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 management practices that improve N use efficiency can help lift productivity and profitability and reduce N_2O emissions.

PHOTO: DEBRA DONOVAN

NANORP research on tillage trials at Buntine, Western Australia, showed up to 80 per cent of annual gaseous nitrogen losses, such as nitrous oxide emissions, occurred in wet, post-harvest conditions.

KEY POINTS

- Plant uptake of nitrogen (N) fertiliser applications as low as 30 per cent shows there is considerable scope to improve N use efficiency and reduce gaseous N losses as nitrous oxide (N_2O) in the grains industry.
- N_2O emissions from Australian cropping systems are low by international standards, but even low emissions provide an indicator of other larger gaseous N losses.
- Better matching N fertiliser inputs to N content in the soil and crop demand by fine-tuning the rate, timing and placement of N applications and choice of fertiliser can reduce N_2O emissions.
- Cropping soils prone to waterlogging and with high concentrations of nitrate-nitrogen (NO_3-N), plus soils transitioning from pasture to cropping, are at high risk of N_2O emissions.

FERTILISER 'EMISSIONS'

Nitrogenous fertiliser is a major, consistent investment in crop growth that Australian grain growers make in order to meet yield 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, annual N_2O emissions measured in the northern grains region were about one to two kilograms per hectare from sorghum.

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 growers.

This fact sheet highlights research relating to the grains 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 soluble 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 (NO) 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 growers, mitigating the denitrification process is important in terms of on-farm productivity and profitability.

NITROGEN AND YIELD

N is an essential macronutrient for grain crop growth and growing a high-yielding crop requires a significant supply of plant-available N. The N required by the crop can come from fertiliser applications, mineralisation of soil organic matter and N-fixing legumes.

NUE AND YIELD

NUE is a measure of how effectively N is taken up by plants for crop growth. Improving NUE increases the crop 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 85 per cent of N fertiliser applications as N gases, mostly as N_2 and N_2O.

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 growers.

Reducing denitrification remains a challenge, however, because grain crops in high-rainfall areas where soils are prone to saturation increases the risk of N losses as N_2O. Irrigated crops are also susceptible to high N_2O emissions due to waterlogging.

ON-FARM PRACTICES TO LIFT CROP NUE

Varying amounts of N available to a crop can be found in harvested grain, but uptake of N fertiliser as low as 30 per cent shows there is considerable scope to improve NUE and reduce gaseous N losses as N_2O in the grains industry.

Better matching N fertiliser applications to N content in the soil and crop demand can help optimise NUE. On-farm practices to help achieve this objective are fine-tuning the rate, timing and placement of N applications and choice of fertiliser.

REGIONAL N_2O EMISSIONS

By international standards, N losses as N_2O emissions from Australian grains operations are low and tend to be significantly lower than high-input cropping systems in Northern Hemisphere countries.

However, NANORP research in Australia's northern, southern and western grain-growing regions found that some Australian cropping soils are susceptible to high N_2O emissions. Specifically, these are: soils prone to waterlogging; those with high concentrations of nitrate-nitrogen (NO_3-N); and soils with high organic carbon content transitioning from a pasture phase to a cropping phase with added N fertiliser.

WESTERN GRAINS REGION

Research exploring sandy cropping soils in a low-rainfall area of Western Australia showed just 0.08 to 0.12 per cent of applied N fertiliser was lost into the atmosphere as N_2O emissions.

The most significant daily N_2O losses occurred in response to summer rain after harvest. Up to 80 per cent of annual gaseous N losses occurred in these wet, post-harvest conditions at the experimental site in WA.

NANORP research indicated that increasing soil organic carbon also resulted in a slight increase in N_2O emissions. But these emissions were outweighed by the benefits of soil organic carbon in lifting grain yield and quality, and in reducing N fertiliser rates.

NORTHERN GRAINS REGION

Research showed dryland sorghum crops in Queensland and northern New South Wales produced more N_2O than dryland wheat crops in WA. However, the emissions from northern farming systems, typically less than one per cent of applied N fertiliser, were still low by international standards.

The research also found N_2O was an indicator of other larger gaseous N losses, such as N_2, as a consequence of denitrification.

For example, annual losses of applied N as N_2O from sorghum were about 1 to 2kg/ha, but up to 80kg/ha, or 40 per cent of annual N applications, were lost from the crop as other N gases, mostly N_2.

In clay soils typical of the northern grains region, low soil carbon generally meant N_2O emissions were also low.

However, double cropping on these heavy soils can lead to high labile (reactive) carbon content in both soils and stubble, which, when combined with waterlogging and high N fertiliser rates, can result in large gaseous N losses, particularly early in the growing season.

Growing N-fixing legumes in rotation can reduce N fertiliser application requirements in the following sorghum crop, without affecting its yield potential, and decrease N_2O emissions per tonne of grain.

SOUTHERN GRAINS REGION

Research recorded some of the highest N_2O emissions from Australian agricultural soils in the high-rainfall cropping zone of south-west Victoria, where annual rainfall is more than 650 millimetres.

Highlighting these significant N losses, emissions of up to 600 grams of nitrous oxide-nitrogen (N_2O-N)/ha per day were measured from soils prone to waterlogging, with high mineral N content (more than 200kg/ha to a depth of 100 centimetres in the profile) often following a pasture phase or extended fallow period, and with high organic carbon content between three and five per cent.

In trials at Horsham, in western Victoria, a medium-rainfall area, between 20 and 40 per cent of applied N was not taken up by crops, suggesting these inputs were lost into the atmosphere as N gas.

In the Wimmera region, trial results generally showed N losses as N_2O emissions were low on soils with low labile carbon and nitrate content, but emissions can escalate where the region's high-clay-content and duplex soils are waterlogged.

Trials examining legumes and canola in southern NSW found these crops used most of the mineral N available in the soil during the growing season and, as a consequence, N_2O emissions mostly occurred following harvest during the summer fallow period when N was mineralised from crop residues.

In a three-year trial at Wagga Wagga, NSW, tillage did not affect N_2O emissions compared with no-till.

Illustrating a worst-case scenario for N_2O emissions, a study at Hamilton, Victoria, showed between 80 and 90 per cent of applied N was unaccounted for at harvest where urea was deep-banded 10cm below the seed at sowing in soils that became saturated or waterlogged during the growing season, and in cropping situations where there was:

- high labile carbon content in cropping soils following cultivation of legume-grass pasture;
- high rainfall leading to low soil oxygen and microbial oxidation of nitrate into gaseous N; and
- high background mineral N content in the soil (resulting from mineralisation before the start of the cropping season).

Measuring soil N before sowing and matching N fertiliser applications to the soil's background N can help maximise NUE and minimise N_2O emissions in medium and high-rainfall cropping regions.

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