NANORP FERTCARE®

National Agricultural Nitrous Oxide Research Program

GRAINS INDUSTRY FACT SHEET

Nitrous oxide emissions in the Grains Industry

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PHOTO: EVAN COLLIS

Nitrogen fertiliser losses from the soil as nitrous oxide gas can escalate following summer rain post-harvest in Western Australia.

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.
- In trials at Hamilton, Victoria, between 80 and 90 per cent of applied N was unaccounted for at harvest where urea was deep-banded 10 centimetres below the seed at sowing in soils that became saturated or waterlogged during the growing season.
- 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 N lost as nitrate, plus soils transitioning from pasture to cropping, are at high risk of N_2O emissions.

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 generally represent inefficient fertiliser use, so lowering the amount of this nitrogen (N) gas lost from the soil could deliver 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 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 N 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 a significant 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 in soils by lightning strikes.

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) though 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 nitric oxide (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 DRIVERS

- In cropping areas, nitrous oxide (N_2O) emissions contribute significantly to whole-farm greenhouse gas emissions.
- N_2O emissions generally occur sporadically and are influenced by the amount of crop stubble (labile carbon), moisture and nitrate (NO_3^-) in the soil.
- When they do occur, nitrogen (N) losses as N_2O can be large and are indicative of much larger losses of dinitrogen.
- Nitrification inhibitors that slow the production of nitrate in the soil have shown potential in reducing N_2O emissions, but are not yet cost-effective.

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 10 centimetres 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 N use efficiency and minimise N_2O emissions in medium and high-rainfall cropping regions.

N_2O AND THE GRAINS INDUSTRY

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 N use efficiency (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 WA showed just 0.08 to 0.12 per cent of applied N fertiliser was lost into the atmosphere as N_2O emissions. However, such low N_2O losses can escalate 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.

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 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 600g of N_20-N/ha per day were measured from soils prone to waterlogging, with high mineral N content (more than 200kg/ha to a depth of 100cm 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. This research in the Wimmera region generally showed N losses as N_2O emissions were low on soils with low labile (reactive) carbon and nitrate content, but emissions can escalate where the region's high-clay-content 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.

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