Best Management Practices to reduce nitrous oxide emissions for irrigated broadacre cropping (excluding rice).
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Nitrous oxide (N\textsubscript{2}O) is a gas which, under certain soil and environmental conditions, is produced from both soil mineralised and fertiliser nitrogen (N) by denitrifying bacteria. For the farmer this represents a loss of soil fertility and/or loss of applied fertiliser. Additionally, when in the atmosphere, N\textsubscript{2}O is a potent greenhouse gas. This is why it is important to minimise the loss of valuable soil and fertiliser nitrogen N to the atmosphere through these processes. This BMP fact sheet sets out how this can be achieved by farmers undertaking broadacre irrigated cropping.

Soil type and irrigation method (flood/furrow/overhead/subsurface) have big effects on nitrous oxide (N\textsubscript{2}O) emissions from irrigated crops.

A number of factors effect N\textsubscript{2}O emissions from soils. For example, wet soils\textsuperscript{1} increase N\textsubscript{2}O emissions particularly when the water-filled soil porosity (WFSP) is above 60%. It follows that crop management decisions can impact on how much N is lost and that optimising the timing, placement and rate of N fertiliser application in relation to environmental conditions and the crop’s nitrogen demand is integral in reducing nitrous oxide emissions. In turn this improves the N use efficiency, which can also improve crop productivity and reduce the cost of production to result in a greater gross margin.

All this means is that through good management N loss to the atmosphere can be minimised.

There are three main drivers of N\textsubscript{2}O emissions from soils

- The amount of labile highly reactive carbon (C) in the soil. This form of carbon is used by denitrifying bacteria as an energy source. Fresh organic matter such as brown and green manure crops, crop stubble, volunteer weeds and manures contribute most of the labile C in our soils. Soils with elevated levels of labile C have the potential to produce higher levels of N\textsubscript{2}O than those with little labile organic C.

- Soil moisture content. Wet soil conditions are the most conducive to N\textsubscript{2}O emissions, and here soil texture is also important because there is a close linkage between drainage of excess water and soil pore sizes. Peak N\textsubscript{2}O emission occurs at around 70% water-filled pore space.

- The amount of nitrate (NO\textsubscript{3}\textsuperscript{-}) in the soil. When the amount of NO\textsubscript{3}\textsuperscript{-} in the soil (whether from N fertilisers, including organic sources such as manures, or from the breakdown of organic matter) exceeds the capacity of the crop to take that NO\textsubscript{3}\textsuperscript{-} up, increased N\textsubscript{2}O emissions is more likely.

Managing an irrigation enterprise to reduce N\textsubscript{2}O emission must include due consideration of the relationship between the soil, water management and N tactics in progressing toward lower emissions. Concentrating on N application tactics alone may yield limited benefit whereas appropriate changes to soil physical and chemical characteristics, irrigation management and N fertiliser tactics together are more likely to provide pathways to more rapid and sustained reductions in emissions.

Soil Parameters

- Soil type – Wet areas in paddocks increase N\textsubscript{2}O emissions and may reduce yields. Soil chemical (i.e. exchangeable sodium percentage, ESP) and physical characteristics (i.e. texture and structure), and your irrigation layout, affect the formation of wet areas.

\textsuperscript{1}The terms wet areas, wet soils and wet patches are used in the context of soil horizons or areas of paddocks above 60% WFSP.
Suggested Practices

Right Rate

Application of nitrogen fertiliser should be limited to the rate necessary to meet projected crop needs. To achieve this, the following points need to be considered:

• Soil water – If possible, only apply N fertiliser when the risks of creating WFSP above 60% are low. Knowing the soil water content, crop demand and weather forecasts can help in this regard.

Irrigation Parameters

• Base water management on objective assessment of soil water status and crop requirements.
• Optimising the slope angle for particular soil types and field lengths, and ensuring a consistent grade, assist in preventing wet soil areas and associated N\(_2\)O emissions.
• Bed shape and dimensions should be matched to the physical characteristics of the soil and the irrigation method to minimise wet soil, optimise water infiltration and, where possible, maintain an aerobic (i.e. not above 60% WFSP) soil environment for the crop.
• Design irrigation layouts and efficient water-use practices to minimise waterlogging and maximise water infiltration.
• Irrigation water application rate and method should be appropriate for the range of crops produced, climate and soil types.
• Water quality should be monitored to ensure its chemical constituents do not reduce soil structural stability. Avoid overuse of highly sodic irrigation water as this can quickly lead to soil structural decline and consequential poor crop growth.

Crop Parameters

• The amount of N required by the crop changes during the growing period according to growing conditions crop species and crop stage. In order not to limit yield, N application strategies should be aimed at supplying the N needs of the crop at all stages and avoiding excess during periods of high risk to minimise denitrification losses.

Nitrogen Supply Parameters (4R’s)

• Right Product – Under wet soil conditions, nitrate (NO\(_3\)\(^-\)) in the soil is converted to oxides of N and dinitrogen (N\(_2\)). It follows that N\(_2\)O emissions are less where ammonium (NH\(_4\)\(^+\)) is the dominant reaction product and its rate of conversion to nitrate in the soil is slowed. Nitrification inhibitors can slow the conversion of NH\(_4\)\(^+\) to NO\(_3\)\(^-\) but its price and logistics need to be considered.
• Right Rate – The optimum N fertiliser rate depends on the crop and the system in which it is growing. Although nitrous oxide emissions may only be a small component of overall N losses from wet soils, it makes sense to consider the other sources of N supply, type of fertiliser, logistics, cost, crop requirements and N emissions when deciding on the appropriate fertiliser application rate.
• Right Time – Fertiliser is a cost to production. Matching fertiliser application to crop demand makes best use of this resource.
• Right Place – Placing the fertiliser in the active root zone is desirable.

Suggested Practices

Right Rate

Application of nitrogen fertiliser should be limited to the rate necessary to meet projected crop needs. To achieve this, the following points need to be considered:

• Soil sampling for mineral N content should be done for every crop where there is a lack of certainty about the quantity and location of mineral N in the effective root zone. For annual crops, it is most appropriate to take samples just prior to planting or early in-crop ahead of post emergence application, particularly in situations that may have higher residual nitrogen levels such as where crops follow low yielding cereal, pulses, ley legumes and where late in crop N has been applied to the previous crop as these are more difficult to estimate.
• Ensure that other nutrients are not limiting crop growth and therefore impacting on the N use efficiency...
(NUE) by either undertaking soil and plant tissue analysis or doing test strips.

- Set realistic yield goals or yield expectations and grain protein targets based on historical yield averages, which type of wheat is being grown (e.g. prime hard, noodle, biscuit wheat), fallow soil moisture and market signals.
- Base the rate of N application on these realistic crop yields, % protein, % oil etc. targets with an allowance for efficiency of N uptake.
- Consider subsoil limitations, such as transient salinity, sodicity and acidity, which restrict the ability of crops to effectively utilise soil N. Nitrogen inputs (from either fertiliser or legumes) should be adjusted (reduced) to reflect the true yield capacity of crops where subsoil limitations are present.
- Take into account N input from other non-fertiliser sources including contributions from
  - Soil mineral N from the pre-plant soil test.
  - Organic matter mineralisation from sampling to crop maturity.
  - Net N mineralisation of residues from previous crops.
  - Prior legume crops or pastures.
  - Manure application.
  - Irrigation water
- Include N from all fertiliser sources applied at all timings relate to the crop.
- Where possible limit pre-plant or planting N rate on crops especially in situations where leaching or denitrification is a possibility and where it is feasible to apply in-crop N. Most crops require very little N in the first few weeks after planting and emergence.
- Where possible split N applications into several applications over the season to meet crop need. This provides the flexibility to adjust rates to the unfolding seasonal conditions and minimises the chances of a large loss of N if conditions go against you with one larger application.
- Consider controlled or slow-release products where cost can be justified and efficacy and reliability are well-defined.
- Calibrate fertiliser application equipment so that you know the rate of N application across the field (unless there is an established reason to vary the rate across the paddock, such as zonal management).
- Monitor N with in-crop soil tests, plant tissue or sap analysis, where applicable, and relate to seasonal forecasts.
- For high N input crops, soil sample for N to the depth of effective root zone after harvest to measure residual N. This can be used as a further guide to N rates in the following season.
- Collect data and calculate indices of nitrogen use efficiency (NUE) regularly to ensure seasonal N tactics are effective.
- Measure grain protein % in cereals and oilseeds as a guide to whole of season N adequacy.

**Right Time / Right Product**

Application of nitrogen fertiliser should be timed to coincide as closely as possible to the periods of maximum crop uptake. While this will vary with region and crop, the following considerations are important:

- Timing of N application should be scheduled with an understanding crop development stages that signify critical N uptake period for all species grown and root structure.
- Timing of N application should account for lag time between fertiliser application and when the product applied is chemically and positionally available for uptake by roots.
- Application timing should take into consideration location of hostile subsoil layers.
- Application should be timed to keep N in the NH$_4^+$ form for as long as possible before crop uptake where there is denitrification and leaching risk.
  - Consider including a nitrification inhibitors where conditions for NO$_3^-$ losses are frequently high and cost can be justified.
- Split-application by top-dress, side-dress or fertigation of N to coincide with the start of rapid crop growth / rapid N uptake.
  - Consider controlled or slow release products where cost can be justified and the release pattern is suitably matched to crop demand.
• Do not apply fertiliser far ahead of crop establishment, unless the risk of denitrification and leaching are minimal e.g. clay soil with low level of stored soil water on sloping topography.
• Do not apply fertiliser ahead of a forecast heavy rainfall event.

**Right Place / Right Product**

Application of nitrogen fertiliser should be by a method designed to deliver nitrogen to the root area for maximum crop uptake

• Always apply fertiliser to the root zone or where there is a reasonable expectation that follow-up rainfall will carry fertiliser into the main root zone.
• Sub-surface application of N products is recommended if they are prone to volatilisation losses or where there is significant risk of erosion of topsoil (e.g. full moisture profile).
• Where urea is surface applied and not manually incorporated, consider local research recommendations about loss potential, consider the local weather forecast or use of a urease inhibitor if economically viable.
• Incorporate controlled or slow-release products where they have proven efficacy.
• Pre-plant band applied N should be placed as deep as practical below the layer of decomposing crop residue.
• Where N is applied in irrigation water, ensure it is applied toward the start of the irrigation rather than at the end and control tail-water containing added N.
• In flooded furrow or bed irrigation systems place pre-plant nitrogen as close to the plant line and as deep below the level of the furrow, as practical.

**Right Product**

Selection of nitrogen fertiliser products should consider

• Preferably supply N as products that are NH$_4^+$ based or produce NH$_4^+$ in their transformation to NO$_3^-$ e.g. urea, anhydrous ammonia, ammonium sulphate, urea solutions.
• Provide as much N from organic matter mineralisation as practical and profitable e.g. green manure, pulse crops, recycled organic matter (composts, crop residues, bio-solids) and manures.
• Manure – obtain an analysis of the nutrient content including organic and total N and make allowance in the fertiliser program for N release characteristics based on manure type, application method, decay coefficient for N and local climatic factors that influence releases pattern.

**In irrigated cropping there are also other management techniques that the grower can use to minimize soil N loss from denitrification, leaching or runoff and maximise NUE**

• Reduce fallow period where there is a high probability of enhanced mineralisation e.g. following legumes.
• Grow deep-rooted crops can be used to mop up the N left in the subsoil by shallow-rooted crops.
• Follow legume crops with high N use crops.
• Ensure fertiliser applicator is switched off at ends of rows, headlands etc. during turning.
• Store fertiliser in a manner which protects it from rain.
• Ensure any spills of fertiliser are picked up immediately.
• Ensure employees who apply fertiliser are trained adequately.
• Consider yield mapping based on GPS enabled data loggers to identify high and low yielding areas within the paddock. Inputs can then be adjusted to increase N use efficiency.
• Select crop species and varieties that are genetically able to make most advantage of the N availability.

**Do nots**

• Nitrate forms should not be applied in large amounts when denitrification or leaching risk is moderate to high.
• Do not use practices that result in soil compaction as good soil drainage is required to prevent waterlogging.

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²For a full description of Australian fertiliser products please refer to Australian Soil Fertility Manual (3rd edition) 2006.
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