Best Management Practices to Reduce Nitrous Oxide Emissions for Annual Vegetable Production.

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Prepared by:
Gerard Fullerton
Back Paddock Company
Email: gfullerton@backpaddock.com.au
Mobile: 0409 992356

With contributions from:
Dr Chris Dowling
Back Paddock Company
Email: cdowling@backpaddock.com.au
Phone: (07) 38213577
Mobile: 0407 692251

Jeff Kraak
Fertilizer Australia
Email: jeff.kraak@fertilizer.org.au
Mobile: 0407 663535

Dr George Rayment
Private Consultant
Email: raymeng@optusnet.com.au
Mobile: 0438 356 252

Julio Vargas
Department of Economic Development, Jobs, Transport and Resources
Email: julio.vargas@ecodev.vic.gov.au
Phone: (03) 53660048
Mobile: 0428 316 018

Ash Wallace
Department of Economic Development, Jobs, Transport and Resources Vic
Email: ashley.wallace@ecodev.vic.gov.au
Phone: (03) 53622135
Mobile: 0429 935400

Charlie Walker
Incitec Pivot Fertilisers Ltd
Email: cwalker@incitecpivot.com.au
Mobile: 0413 018547

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Best Management Practices (BMP) to reduce nitrous oxide emissions for annual vegetable production.

Managing Denitrification Risk – significant factors

Nitrous oxide (N_2O) is a gas which under certain soil and environmental conditions is produced from both soil mineralised and fertiliser nitrogen (N) by de-nitrifying bacteria. For the farmer this represents a loss of soil fertility and/or loss of applied fertiliser. Additionally, when in the atmosphere N_2O is a potent greenhouse gas. This is why it is important to minimise the loss of valuable soil and fertiliser N to the atmosphere through these processes. This BMP fact sheet sets out how this can be achieved by farmers producing vegetables.

A number of factors effect N_2O emissions from soils, for example wet soils[1] increase N_2O 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 N demand is integral in reducing nitrous oxide and other gaseous N 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_2O emissions from soils:

- **The amount of labile carbon (C) in the soil**. This form of carbon is used by de-nitrifying bacteria as an energy source. Fresh organic matter such as brown and green manure crops, 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_2O than those with little labile C.
- **Soil moisture content**. Waterlogged conditions are the most conducive to N_2O emissions and here soil texture is important because there is a close linkage between drainage of excess water and soil pore sizes. Peak N_2O emissions occurs at around 70% water filled soil porosity.
- **The amount of nitrate (NO_3^-) in the soil**. When the amount of NO_3^- in the soil (whether from N fertilisers, including organic sources such as manures, or from the breakdown of organic matter) exceeds the capacity of crop to take that NO_3^- up, increased N_2O emissions is more likely.

Managing an irrigation enterprise to reduce N_2O emission must include due consideration of the relationship between the soil, water management and nitrogen use practices in progressing toward lower emissions. Concentrating on the N use practices alone may yield little progress whereas appropriate changes to soil physical and chemical characteristics, irrigation management as well as N fertiliser use practices could together provide a pathway to more rapid and sustained reductions in emissions.

Soil Parameters

- Soil type – consider the interaction of chemical and physical characteristics on denitrification potential.
- Soil water – assess the risk of applying N with knowledge of soil water content and forecast rain from general climate data.

Irrigation Parameters

- Base water management on objective assessment of soil water status and crop requirements.
- Optimising the slope angle for

[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.

particular soil types and field lengths as well as ensuring a consistent grade assist in preventing wet soil areas and associated N_2O 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 rate/s.
- Water application rate and method.
- Water quality – water quality should be monitored to ensure its chemistry does not cause a decline in the stability of physical soil characteristics. 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 and leaching losses.

Nitrogen Supply Parameters (4R's)

Fertiliser is a cost to production; the more efficiently it is applied and used by the crop the better for production, profit and the environment.

- **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_2O emissions are less where ammonium (NH_4^+) is the dominant N form and its rate of conversion to NO_3^- in the soil is slowed. Nitrification inhibitors can slow the conversion of NH_4^+ to NO_3^- but the 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. Nitrous oxide emissions may only be 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** – 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 Best Management Practices to reduce nitrous oxide emissions and improve fertiliser use efficiency

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:

- Match soil N supply to crop N demand. Set realistic yield goals or yield expectations based on historical yield averages and seasonal conditions and an allowance for efficiency of uptake.
- Ensure that other nutrients are not limiting crop growth and therefore impacting on the nitrogen use efficiency (NUE) by either undertaking soil and plant tissue analysis or doing test strips. Soil sample 0 – 15cm before crop is planted on a regular basis to test for pH, Electrical Conductivity and nutrients including N.
- Take into account N from:
    - o Soil mineral N from the pre-plant soil test
    - o Organic matter mineralisation from sampling to harvest
    - o Residues from previous crops
    - o Prior legume crops
    - o Organic material application e.g. compost, manure
    - o Irrigation water
    - o All fertiliser sources including planting fertiliser.

- Limit pre-plant or planting N rate on crops / situations where leaching or denitrification is a possibility and where it is feasible to apply in-crop N. Crop N demand in the first few weeks after planting and emergence or after transplanting is usually very low. Soil test pre-plant to determine soil nitrate N level and requirement for N at planting.
- Apply remaining N rate split into several/ many applications over the season to meet crop needs.
- Consider controlled release products or nitrification inhibitors where leaching or denitrification is likely.
- Calibrate fertiliser equipment so you know the rate of N application and ensure uniformity of application across the paddock (unless there is a reason to vary the rate across the paddock).
- Pre-sidedress soil nitrate test (PSNT) - soil sample 0 - 30 cm for nitrate N before the initial in-season N application and adjust N rate based on residual nitrate N with a value of >20 mg N/kg separating "necessary to use N top-dressing" from "unnecessary to use N top-dressing or only necessary to top-dress at a reduced rate". Repeated in-crop soil nitrate N testing can be used where soil nitrate N levels are initially high.
- Monitor in-crop with plant tissue or sap analysis where applicable.
- On high N input crops soil sample for N at 0 - 30 cm or to the depth of effective root zone after harvest to measure residual N (further guide to suitability of N rate used).

Right Product[2]

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.
- When N is supplied in the NO_3^- form, only apply as much N as the crop can take up in the short term.
- Provide as much N from organic matter mineralisation as practical and profitable e.g. greenmanure, 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 co-efficient for N and local climatic factors that influence release pattern.

Right Time / Right Product

Application of nitrogen fertiliser should be timed to coincide as closely as possible to the periods of maximum crop uptake:

- Do not apply fertiliser far ahead of crop establishment, unless using a production practice such as plastic mulch to protect the fertiliser from leaching by rainfall.
- Split-application by topdress, sidedress or fertigation of N to coincide with the start of rapid crop growth / rapid N uptake
    - o Know the crop's N uptake pattern and match it with N fertiliser application.
- Keep N in ammonium form for as long as possible before crop uptake where denitrification and leaching are possibilities
    - o consider the use of nitrification inhibitors where conditions for nitrate losses from leaching or denitrification are high and cost can be justified
    - o consider the use of controlled release products where conditions for nitrate losses from leaching or denitrification are high and cost can be justified.
- 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 and minimum loss:

- Always apply soil-applied fertiliser in a manner so that the majority will stay in the root zone.
- Subsurface application of N products is recommended – this can be by mechanical means or irrigation.
- Incorporate controlled or slow release products.
- Where urea is surface applied and not incorporated, consider use of a urease inhibitor.

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

Keeping fertiliser in the Right Place

Application of irrigation water to meet crop needs should be managed to minimize nitrogen loss by denitrification, leaching and runoff:

- Ensure high irrigation efficiency and uniformity (good system design and operation).
- Avoid large irrigation volumes after fertilization or when the soil mineral N content is high.
- Irrigation should be managed to minimise run-off and deep drainage by matching irrigation volumes to soil water deficit.
- Weather and climate forecasting should be used when making irrigation decisions.
- Nitrogen applied in irrigation water should be through a calibrated device.
- Fertigation solutions should be calibrated, monitored and managed to ensure applications are evenly applying the N rate required.
- Tailwater recovery should be considered to capture and recycle nutrients. Monitor N in tailwater.

The application of irrigation water should be timed to minimize nitrogen loss by denitrification, leaching and runoff:

- Schedule irrigation according to soil moisture depletion, crop water needs and rainfall likelihood.
- Schedule irrigation and fertilisation events to minimise N loss

The operator should use tillage practices that maximize water and nitrogen uptake by crop plants:

- Laser level irrigation paddocks to remove low spots (potential wet areas) and improve drainage.
- Plant on beds if waterlogging is expected at certain times of year.
- Avoid practices that result in soil compaction - minimise compacted soil zones.
- Avoid tillage under wet conditions – mineralised N is especially susceptible to losses following tillage under wet conditions especially if organic C level is high.

Other methods to minimize nitrogen loss from denitrification, leaching or runoff:

- Deep rooted non-legume crops can be used to mop up the N left in the surface and subsoil by shallow rooted vegetable crops. If soil nitrate N residue is very high, these crops may have to be removed from the paddock as hay or silage otherwise should be brown or green manured at a time when leaching loss risk is minimised and surface dry matter is unlikely to interfere with crop establishment activities.
- Follow legume crops with high N use crops.
- Identify high and low yielding areas within the paddock. Match N inputs accordingly where technically feasible to increase N use efficiency.
- 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.

Do nots

- Do not apply NO_3^- forms in large amounts when denitrification or leaching hazard is moderate to high.
- Do not apply N through low efficiency furrow systems where waterlogging or deep drainage is likely.
- Do not apply fertiliser when runoff from storms is expected before the nutrient can penetrate the root zone.
- Do not use practices that result in soil compaction as good soil drainage is required to prevent waterlogging.

Other

- Manure – obtain an analysis of the nutrient content including organic and total N or adjust N rate of applied fertiliser based on indicative mineral N content of the manure and N applied.
- Records should be kept of soil tests, products used, application rates, placement, time, calibration of equipment and person applying.

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