Best Management Practices to Reduce Nitrous Oxide Emissions for Fruit, Nut and Grape Production Systems.

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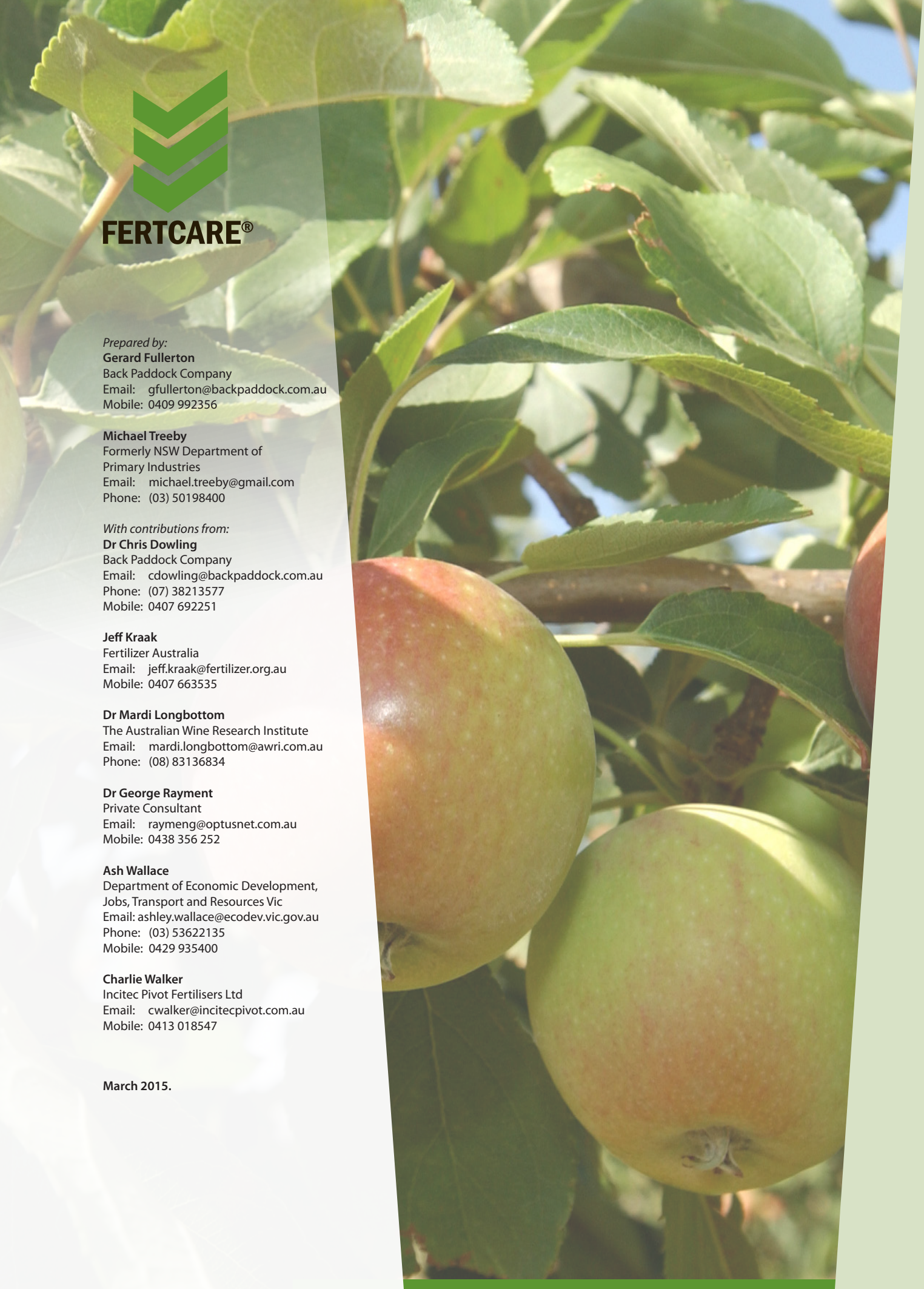

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March 2015.

Fertcare® Carbon Farming Extension Project

Best Management Practices (BMP) to reduce nitrous oxide emissions for fruit, nut and grape production systems.

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 fruit, nut and vine crops.

A number of factors affect 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 C 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 also important because there is a close linkage between drainage of excess water and soil pore sizes. Peak N_2O emission occurs at around 70% water filled pore space.
- **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.

Principles for Managing Denitrification Risk – significant factors

Managing an irrigation enterprise to reduce N_2O emission must include due consideration of the relationship between the soil, water management and N 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.

It is important to know about the soil and what is happening in it:

- The amount of readily available water that can be held in the rootzone is the critical piece of information needed by all fruit, nut and grape producers to manage their crops' water needs. This

[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.

information is also critical to avoiding losses of N fertiliser, either through leaching or N_2O emissions. The depth and the soil texture of the rootzone need to be known to estimate the water holding capacity of that part of the soil profile for each irrigation shift. This information is gathered during soil surveys conducted as a prelude to designing and managing modern irrigation systems. Some of it may already exist in soil surveys conducted previously.

- Maintaining adequate soil moisture levels is important for good tree/vine health. This includes the need to avoid waterlogging conditions. Being able to measure soil moisture is therefore critical to avoiding these circumstances as N_2O emissions are more likely. Considering both weather forecasts and soil moisture measurements is useful when assessing the risk of applying N.
- The soil's chemistry is also critical because some soils may be inclined to sodicity which results in structural decline of the soil and more localised waterlogging.

Designing and managing irrigation systems:

- The irrigation design needs to accommodate differing soil types across the property because some soil types will need to be irrigated more frequently than others due to the differing amounts of readily available water each can hold.
- Only apply as much water as needed. This means only filling the root zone, not beyond, and where possible, maintain an aerobic (i.e. not above 60% WFSP) soil environment for the crop.
- Avoid overuse of highly sodic irrigation water as this can lead to soil structural decline, poor water infiltration, waterlogging of the surface soil and poor tree/vine health.

Nitrogen Supply Parameters (4Rs)

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. Logistical and economic considerations are an important part of the decision to choose one form over another, but tree/vine roots have no preference for one form over any other.
- **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. Application must be linked to crop phenology. There is little point applying N fertiliser to deciduous crops such as grapes or apples during the dormant season, and there is little point applying N fertilisers to vineyards and orchards when the soil temperature is too low for root growth.
- Right Place – Placing the fertiliser in the active root zone is desirable. Fertigation is widely practiced in vineyards and orchards and is a good method of delivering any soluble fertiliser to the rootzone where the chance of being taken up by the crop roots is much higher than if the fertiliser was applied to the soil surface only. This means irrigation management is critical, as is timing and the amount of fertiliser supplied.

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:

- Historical rates are a good starting point, but the effectiveness of the fertiliser program needs to be evaluated and the program modified using
  - o visual examinations of tree and vine growth
  - o fruit yields relative to the district or regional averages for that variety/ rootstock combination and past yields off that particular management unit and
  - o plant tissue tests and comparison with established interpretative standards.
- States' agriculture departments and industry-based development officers are good sources of historical rates and this knowledge can frequently be found in on-line factsheets.
- Some allowance always needs to be made for uptake efficiency. As a rule of thumb, the efficiency of uptake from surface applications can be expected to be less than that of applications directly into the rootzone. Nitrogen use efficiency (NUE) is seldom likely to be any more than 50 - 60%, but appropriate timing, and delivery to where it is most likely to be taken up coupled with good irrigation management will push the NUE up.
- All sources of N need to be taken into account when estimating rates. These include:
  - o organic materials applied (for example, compost and manures)
  - o irrigation water (not likely to be high, but worth checking)
  - o inter-row legume crops (can be significant; of the order of 10s of kg N/ha)
  - o all fertilisers applied during any part of the year for whatever purpose.
- Apply N rate split into several applications over the season to meet crop needs.
- If using surface application, calibrate fertiliser spreaders to ensure uniformity of application across management units.
- Consider separate valving for groups of vines/trees with consistently greater or lesser growth/yields than the other vines/ trees in that irrigation management unit.
- Consider variable rate technology in the long term for groups of vines/trees with consistently greater or lesser growth/yields than the other vines/trees in that management unit.

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. 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 co-efficient for N and local climatic factors that influence releases pattern.

Right Time / Right Product

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

- Know the crop's N uptake pattern and match N fertiliser applications to that pattern.
- All perennial crops, whether deciduous or evergreen, store N in the permanent

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

wood over winter to support the spring growth. Most of that N was taken up during the previous growing season. The extent to which each perennial crop is dependent on N mobilised during spring differs, as does the timing of the onset of significant uptake:

  - o grapevines start taking up N significantly around a week before flowering though to veraison, and then again after harvest up to around mid-April in warm regions;
  - o pome fruit (apples and pears) behave in a similar manner to grapevines. Most N used in spring comes from the permanent wood and the roots, not from uptake, which doesn't start in earnest until mid-late October;
  - o almonds start taking up significant amounts of N in early October;
  - o other deciduous nut trees, such as walnut, hazel nut, pecan and pistachio, are similar to almonds;
  - o citrus starts taking up significant amounts of N from early October when soils warm, and continue through to March, with uptake tapering off significantly from early February onwards;
  - o olives behave very much like citrus, with the exception that the leaves are a good source of N during spring; about 40% of the annual requirement is taken up by fruit set, 70% by pit hardening and the remainder by harvest;
  - o macadamias, a sub-tropical evergreen, need small applications over the summer during nut development and oil accumulation; excessive N reduces quality; rates are determined by crop load.

- Irrespective of the application method, splitting the annual supply into several applications reduces the risk of loss, and allows producers to modify the program as the season progresses.
- Controlled release fertilisers are only likely to be economical in high value crops such as herbs and nursery plants.
- Always take into account the likelihood of rain over the next 10 days before applying N, and modify irrigation schedules to minimise the chance that the amount of irrigation water to be applied and the forecast amount of rain don't exceed the water holding capacity of the rootzone.
- Consider supplying N in the ammonium form while soils are cool and wet and denitrification and leaching are possibilities before uptake by the crops' roots kicks in. Consider use of nitrification inhibitors where conditions for nitrate losses from leaching or denitrification are high and cost can be justified.
- Ensure injection equipment is working correctly, and time injections to ensure that no N is left in the dripper tape and pipelines at the end of the irrigation cycle.

Right Place / Right Product

Application of nitrogen fertiliser should be by a method designed to place nitrogen in the area of maximum crop uptake:

- Sub-surface application of N products is recommended – this can also be by irrigation for surface applied granular products.
- If using furrow irrigation, apply N to the area beneath the tree canopy, or side dress onto tree line, and then apply a light irrigation that wets the tree line by capillary action only. Applying N fertilisers to the inter-row area in furrow irrigated vineyards/orchards will result in most of the N being rinsed to the bottom of the row, and being subjected to waterlogging and leaching below the rootzone. Significant losses are likely.
- Where urea is applied to the soil surface and not incorporated by irrigation or cultivation, consider use of a urease inhibitor.
- Use cover crops or pasture in the inter-tree area to recover and recycle fertiliser applied to or moving to this area.

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).
- Match application volumes to soil water deficit and the amount of readily available water that can be held in the rootzone.
- Use weather forecasts and rainfall records when making irrigation decisions; generally, actual and projected rainfall less than 5 mm can be ignored for scheduling purposes.
- Fertigation systems should be calibrated, maintained and managed to ensure applications are within specified program limits.
- Monitor NO_3^- in drainage water if possible. Capture and re-use drainage water providing disease is not an issue.

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

- Consider laser levelling on greenfield sites to slow down potential surface runoff, remove low spots and improve drainage.
- Plant new areas on mounds where waterlogging could be expected at any time of year.
- Avoid practices that result in soil compaction.
- Avoid tillage under wet conditions – mineralised N is especially susceptible to losses following tillage under wet conditions especially if organic C levels are high.

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

- Protect stored fertilisers from rain.
- Ensure any fertiliser spills are cleaned up immediately.
- Ensure employees who apply fertiliser are trained adequately.
- Ensure fertiliser applicator is switched off at ends of rows when turning.
- Consider yield mapping based on GPS enabled data loggers to identify high and low yielding areas within the orchard or vineyard. Inputs can then be adjusted to increase N use efficiency.

Do nots

- Don't apply annual N requirement in any form in one application (unless using a specially selected controlled release product matched to crop uptake pattern).
- Don't apply fertiliser to areas where the vine/tree roots don't have significant access and could be subject to movement down the inter-row area, leaching and denitrification.
- Don't apply fertiliser when runoff from storms is likely before any surface applied N can be moved into the soil by irrigation or cultivation.
- Don't use practices that result in soil compaction.

Other considerations

- Manure – the composition of animal manures varies enormously. Always obtain an up-to-date sheet for the material being applied that specifies the levels of organic and total N, and adjust the rate of applied N fertiliser to take account of the indicative mineral N content in the manure applied. Schedule manure application times so release of N from the material coincides with crop N uptake.
- Maintain records of all soil and tissue tests, irrigation applications, rainfall, materials/products used, application rates and timing, placement, calibration of equipment and personnel involved.

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Acknowledgements:
This project is supported by funding from the Australian Government, in-kind support from Department of Economic Development, Jobs, Transport and Resources Vic, Fertilizer Australia and the wider fertiliser industry.