The Australian Wine Research Institute

Fact Sheet

VITICULTURE

Nitrous oxide management in viticulture

Background

Nitrous oxide (N_2O) is a potent greenhouse gas with a 100-year global warming potential 298 times that of carbon dioxide (Victor et al. 2014). N_2O is a major radiative forcing gas, that is, it significantly retards the insolation energy absorbed by the Earth from being radiated back to space (Myhre et al. 2015). It is also responsible for significant stratospheric ozone-depletion (Portmann et al. 2012).

The major source of N_2O from soils is from the natural microbial processes of nitrification and denitrification (Bremner 1997). Agricultural N_2O emissions are primarily a result of the addition of synthetic nitrogen (N) fertilisers and animal manure to soil. Nitrifying and denitrifying bacteria in the soil convert nitrogen into different forms depending on the soil environment.

What is nitrification?

Nitrification is the aerobic process by which ammonium (NH_4^+) is oxidised to nitrite (NO_2^-) then further oxidised to nitrate (NO_3^-). The rate of nitrification in soil is strongly influenced by temperature and moisture, and increases by a factor of 3.6 for each 10 C increase between 5 and 25 C (Chen et al. 2010). Denitrification is the anaerobic process by which NO_3^- is reduced to N_2O and nitrogen gas (N_2). Denitrification rates are influenced by many factors including soil pH, degree of anaerobicity of soil, soil carbon content, NO_3^- content and water content (Dalal 1998) (Figure 1).

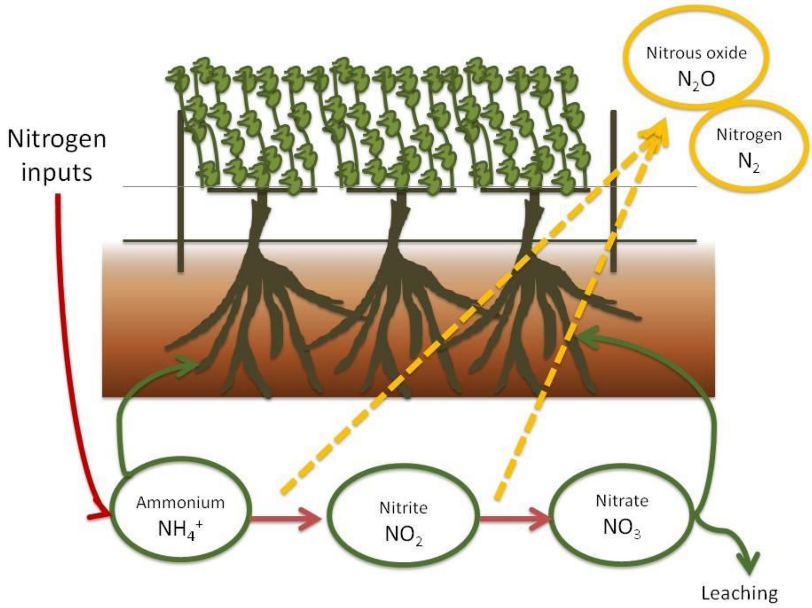

Figure 1. The nitrogen cycle in vineyards. Nitrous oxide is produced by the conversion of nitrogen in the soil.

Management practices to mitigate N_2O emissions

The application of nitrogen to the vineyard

Organic amendments (e.g. manures, composts and mulches) are often applied to agricultural soils to supplement the soil with nitrogen. All inputs of N, whether from organic sources or synthetic fertilisers, contribute to N_2O emissions (Suddick et al. 2011). The magnitude of the N_2O emissions is dependent on soil nitrogen and carbon content, soil moisture, pH and temperature.

It is critical to apply nitrogen at the correct time to maximise uptake efficiency and to prevent N_2O loss. Nitrogen fertiliser should only be applied to vineyards during periods of active root growth. In a Mediterranean climate, this occurs just before flowering and post-harvest. The application of nitrogen at other times during the season will result in nitrogen leaching and loss and may also lead to higher N_2O emissions.

Soil cultivation

The reduction of tillage intensity is often cited as a preferable soil management system because of the benefits of reduced fuel emissions, increased soil carbon and consequent water holding capacity and the offset in atmospheric CO_2. However, the effect of tillage on N_2O emissions in vineyards is inconclusive (Suddick et al. 2011). In theory, tillage increases N_2O due to accumulation of NO_3^- and higher rates of denitrification (Suddick et al. 2011). Steenwerth and Belina (2010) measured higher N_2O emissions from a bare, herbicide-treated vine row compared to a cultivated vine row. The higher emissions measured from the herbicide-treated vine row were thought to have occurred because there were more weeds growing in the cultivated treatment which extracted any available nitrogen from the soil and thus depleted the nitrogen available to the soil microbes. It was also thought that the greater presence of weeds in the cultivated soils might provide labile soil carbon substrates that could facilitate greater conversion of N_2O

to N_2 (Suddick et al. 2011). Garland et al. (2011) also found no significant difference in N_2O emissions from a no-till system and a conventional tillage system in a vineyard.

Irrigation

Water and nitrogen are two significant limiting factors to wine-grape production that are intrinsically linked to N_2O production. Irrigation and nitrogen stimulate plant growth, which may also enhance C storage in soils. Irrigation can also accelerate microbial turnover of C and N, which increases the potential for N_2O production (Suddick et al. 2011). However, irrigation can also prevent losses of N to the environment; for example when incorporated using fertigation, volatilisation can be minimised.

A range of irrigation techniques have been trialled for their effect on N_2O and CO_2 emissions and have demonstrated the capacity to reduce N_2O emissions both cumulatively and also temporally. In almonds, sub-surface drip irrigation (SSD) has significantly reduced N_2O emissions (by 50%) compared to furrow irrigation. N_2O emissions from SSD were also significantly lower than surface drip irrigation when measured in the tree row for four days after fertiliser application. Surface drip and microsprinkler irrigation led to slightly higher N_2O fluxes due to the higher volume of irrigation delivered to the soil. The decrease in N_2O measured under a SSD irrigation system is a result of restricted microbial activity and anaerobic microsite development, which limits denitrification (Suddick et al. 2011). The use of SSD has other advantages including the reduction of evaporative losses from the soil surface; however it is not widely adopted in viticulture due to the increased difficulty of maintenance compared to above ground drip systems.

Acknowledgement

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References and further reading

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