Growing practices to reduce nitrous oxide emissions from processing tomato production

Nitrogen is a key input into processing tomato production. Applying high levels of nitrogen is necessary to achieve high yields but it can also result in nitrous oxide gas being released into the atmosphere from the soil.

Nitrous oxide is a powerful greenhouse gas and is responsible for the majority of emissions from the Australian vegetable industry after CO_2 associated with electricity production for cooling and pumping.

Loss of plant available nitrogen

Nitrous oxide (N_2O) gas is produced by soil bacteria. When the soil is low in oxygen, bacteria use oxygen from nitrate (NO_3), converting it to nitrous oxide or to nitrogen gas (N_2) through denitrification (Figure 1).

This conversion is at the expense of plant available nitrogen and represents a waste of nitrogen fertiliser. Nitrous oxide emissions can also be used as an indicator of the much greater losses of plant available nitrogen through denitrification.

Nitrous oxide is a serious pollutant

Nitrous oxide is a serious pollutant. As a greenhouse gas it has 300 times the warming potential of carbon dioxide[1]. Nitrous oxide is also now the most significant ozone destroying pollutant[2], increasing the levels of ultraviolet radiation and incidence of skin cancers.

Take home messages

- The growing practices currently used by the Australian processing tomato sector can produce low nitrous oxide emissions
- Crop establishment is the greatest risk period for nitrous oxide emissions
- Water and nitrogen management are the key to managing nitrous oxide emissions during planting and throughout the growing season
- Applying a greater proportion of the nitrogen fertiliser as fertigation and less as a basal fertiliser helps reduce nitrous oxide emissions
- Metham sodium application prior to planting inadvertently reduces nitrous oxide emissions by killing soil microbes
- Adding organic matter is great for the soil but it does increase the risk of nitrous oxide emissions.

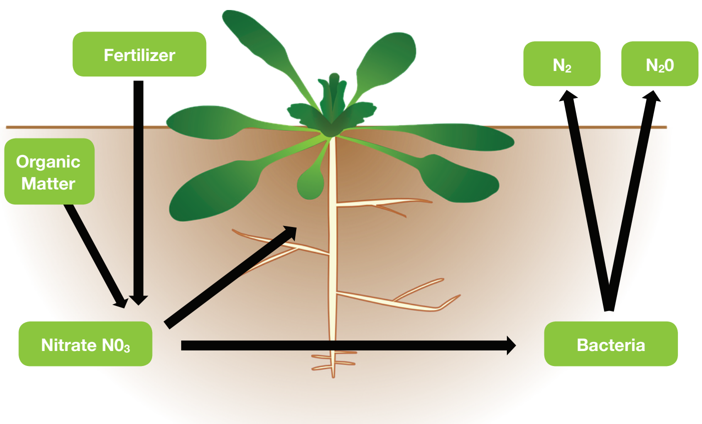

Figure 1: Simplified nitrogen cycle in vegetable soils.

[1] Rezaei Rashti, M., Wang, W., Moody, P., Chen, C., Ghadiri, H. Fertiliser-induced nitrous oxide emissions from vegetable production in the world and the regulating factors: A review (2015) Atmospheric Environment, 112, pp. 225-233.

[2] Portmann, R.W., Daniel, J.S., Ravishankara, A.R. Stratospheric ozone depletion due to nitrous oxide: Influences of other gases (2012) Philosophical Transactions of the Royal Society B: Biological Sciences, 367 (1593), pp. 1256-1264.

This project has been funded by Horticulture Innovation Australia Limited using the funds from the Australian Processing Tomato Research Council and funds from the Australian Government.

Growing practices to reduce nitrous oxide emissions

Low nitrous oxide emissions from Australian processing tomato production are possible

The growing practices used by Australian growers can produce low nitrous oxide emissions.[3] Soil nitrous oxide emissions during the growth of the tomatoes typically averaged 0.35 kg N_2O-N ha^{-1}, which is less than 20% of international average emissions from vegetable crops.[4]

Even more impressive is the very low emissions per tonne of fruit, or emissions intensity. At a mere 5 g N_2O-N tonne $fruit^{-1}$ processing tomatoes produced in Australia are substantially lower than other fresh or grain crops.

But higher nitrous oxide emissions can be produced when growing processing tomatoes (e.g. Figure 3). Below practices to keep emission low or further reduce emissions and nitrogen losses are summarised.

Planting – the greatest risk period for nitrous oxide emissions

Crop establishment is the greatest risk period for nitrous oxide emissions. Subsurface drip irrigation at planting requires excess water to be applied to wet the soil surface (Figure 2). Because of the reliance on subsurface drip this cannot be avoided.

Reducing nitrous oxide emissions during planting by:

1. **Subsurface irrigation system design taking into account the need to irrigate at planting, e.g. depth of dripline, flow rates, etc.**
2. **Managing soil nitrate levels to ensure soil nitrate levels are not high during planting.**
3. **The use of metham sodium soil fumigation reduces nitrous oxide emissions during this period by reducing soil microbial activity.**

[3] Kelvin Montagu, Stephen Moore, Liam Southam-Rogers, Nugen Phi Hung, Liz Mann and Gordon Rogers. Low nitrous oxides emissions from Australian processing tomato crops – a win for the environment, our health and farm productivity (2016). Acta Horticulturae (in press).

[4] Liu, Q., Qin, Y., Zou, J., Guo, Y., Gao, Z., (2013). Annual nitrous oxide emissions from open-air and greenhouse vegetable cropping systems in China. Plant Soil, 1-11.

Water and Nitrogen – the key to managing nitrous oxide emissions

Excess water in the soil causes the soil microbes to run out of oxygen. Rather than suffocating they look for other forms of oxygen, such as in nitrate (NO_3), to continue to functioning.

Managing irrigation, and to a lesser extent growing season rainfall, to avoid excess soil water goes a long way to reducing the risk of nitrous oxide emissions.

Irrigation

Processing tomato production in Australia is now almost exclusively irrigated with subsurface drip. The wide spread usage of subsurface drip irrigation and fertigation by the Australian processing tomato industry has reduced the risk of nitrous oxide emissions, except at planting.

The use of subsurface drip irrigation combined with nitrogen fertigation can reduce nitrous oxide emissions by over 70% compared to furrow irrigation[5].

Figure 2. Typical conditions at planting where drip irrigation saturates the soil to achieve wetting up of the soil.

Growing season rainfall

Within season rainfall can cause large nitrous oxide emissions.

Managing within season rainfall to reduce nitrous oxide by:

1. **If rain is forecast, hold back on irrigation to make some space in the soil for the rainfall.**
2. **Match nitrogen fertiliser application to plant requirements so that soil nitrate levels are not excessive. This is easier when a greater proportion of the nitrogen requirements are met by fertigation.**

Nitrogen fertiliser

The Australian processing tomato industry typically applies 150–250 kg N ha^{-1} of nitrogen fertiliser as a mix of basal fertiliser prior to planting and fertigation during the growing season. The application of nitrogen fertiliser increases the amount of nitrate in the soil, which is required for plant growth. But if high levels of nitrate are present when the soil becomes saturated then very high rates of nitrous oxide emissions can be produced.

Nitrous oxide emissions can be reduced by:

1. **Applying a greater proportion of the nitrogen fertiliser as fertigation. The lowest nitrous oxide emissions occur when 70–80% of the total amount of fertiliser is applied via fertigation and only 20–30% applied as basal fertiliser.**
2. **Soil sampling before planting will tell you how much nitrogen is already available – you might be able to reduce your basal fertiliser rate.**
3. **Match nitrogen fertiliser application to plant requirements so that soil nitrate levels do not build up in the soil.**
4. **Ammonia-based and slow-release fertilisers can reduce nitrous oxide emissions.**

Metham sodium

Metham sodium is a broad spectrum biocide widely used as a soil fumigant in processing tomato production. In addition to killing weeds, it also acts against all soil microbes including those which are involved in the transformation of nitrogen in the soil (figure 1). Typically, the soil biology takes 6–8 weeks to recover after the application of metham sodium.

Metham sodium application prior to planting inadvertently reduces nitrous oxide emissions up to 80% by killing soil microbes.[3]

[5] Kennedy, TL., Suddick, EC., and Six, J., (2013). Reduced nitrous oxide emissions and increased yields in California tomato cropping systems under drip irrigation and fertigation. Agriculture, Ecosystems and Environment 170, 16–27.

Growing practices to reduce nitrous oxide emissions

It's a summer issue

Soil temperature has a major impact on the activity of soil bacteria, which produce nitrous oxide emissions. As a rule of thumb, nitrous oxide emissions are low when the soil temperature is below 15°C.

With the processing tomato industry concentrated into Northern Victoria the greatest risk of nitrous emissions is late spring-summer-early autumn.

Practices to reduce nitrous oxide emissions should focus on late spring – summer – early autumn when soils are above 15°C.

Add organic matter to the soil but don't apply nitrogen fertiliser at the same time

Adding organic matter is great for the soil but is does increase the risk of nitrous oxide emissions. Soil bacteria feed on soil organic matter, and they need oxygen to process this food, just like we do. When large amounts of organic matter is added, the heightened bacteria activity can use all the available oxygen and force soil bacteria to look for alternative sources of oxygen such as nitrate.

To reduce the risk of increasing nitrous oxide emissions:

1. **Apply nitrogen fertiliser after the organic matter from cover crops or crop residues has been incorporated and allowed to be decomposed by soil microbes. Typically, this will be 7–10 days for cover crops if the soil is moist and warm.**
2. **Reduce nitrogen fertiliser rates if using legume cover crops to account for the nitrogen added. Typically, 20-25 kgN per tonne of shoot dry matter is fixed by legume cover crops.[6]**

Sequester carbon in the soil, or mitigate nitrous oxide emissions?

Soil carbon content is a driver of nitrous oxide emissions so doing things that increase soil carbon can work against nitrous oxide abatement. Conversely, pursuing nitrous oxide abatement can work against soil carbon sequestration. The whole system must be considered to ensure that its total carbon footprint is lowered, not just one aspect of it.

[6] Mark Peoples (2009). The legume story – how much nitrogen do legumes fix?. Farming Ahead. June 2009 pp50-52.

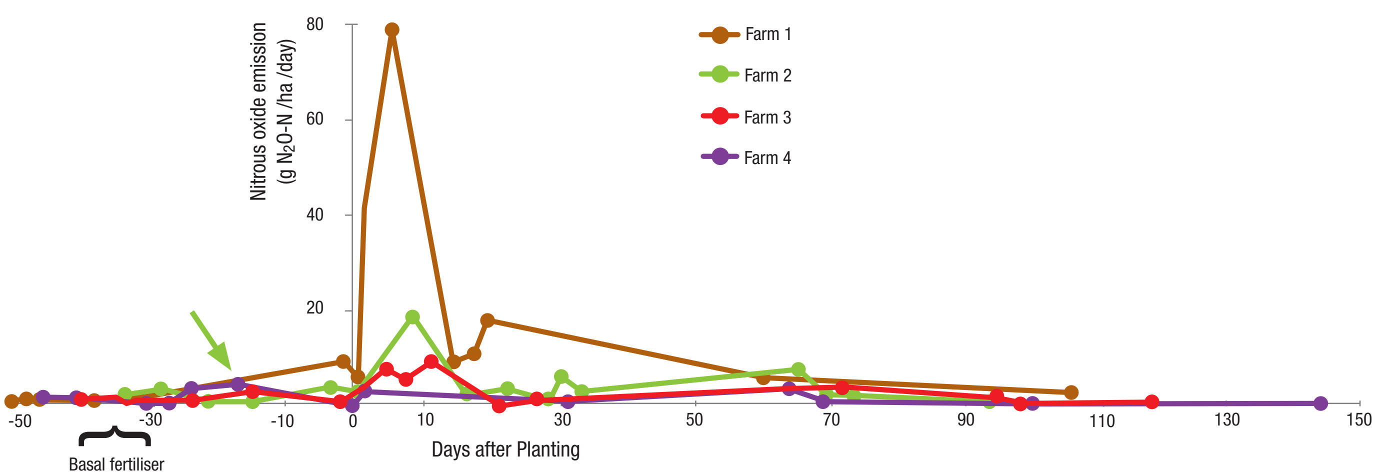

Figure 3. Nitrous oxide emissions from four farms producing processing tomatoes. Farms 2-4 produced very low emissions. High emissions were observed from Farm 1 at planting due to the high use of basal nitrogen fertiliser[3].