The impact of subsurface trickle irrigation and improved soil management on the greenhouse gas emissions from Australian processing tomato crops

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Summary

Nitrous oxide is a potent greenhouse gas. It can also increase ultraviolet radiation transmission and incidence of skin cancers by depleting the ozone layer, and is a waste of applied nitrogen fertiliser.

Nitrous oxide emissions from four commercial farms growing processing tomatoes (*Solanum lycopersicum*) in the Rochester-Echuca-Boort area of Victoria, Australia were monitored during the 2014–15 and 2015–16 growing seasons. Low crop nitrous oxide emissions were measured, ranging from 0.23 to 1.51kg N_2O-N ha^{-1} across the four farms. The emissions intensity of the four farms was very low, ranging from 0.0014 to 0.011 kg N_2O-N tonne $fruit^{-1}$.

The greatest risk period for nitrous oxide emissions was during plant establishment due to the reliance on sub-surface drip and the need to apply excess water to wet the soil surface. Inadvertently, the application of metham sodium appears responsible for reducing average nitrous oxide emissions over the high-risk plant establishment period.

In 2015, emissions after planting were 4.5 times greater when no metham sodium was applied. The low measured nitrous oxide emissions meant that the Cool Farm Tool, the main industry reporting tool, produced nitrous oxide emission estimates that were up to 11 times higher than those measured during the 2014–15 season. When compared to other produce, the Australian processing tomato sector is well placed with very low emissions intensities.

Keywords

Greenhouse gas, nitrous oxide, tomato, metham sodium, Cool Farm Tool

Introduction

Nitrous oxide (N_2O) is now the single most important ozone depleting anthropogenic emission, and likely to remain so, for most of the 21st century (Ravishankara, et al., 2009). It has a global warming potential 298 times greater than carbon dioxide on a per molecule basis (Myhre, 2013).

Nitrous oxide is currently unregulated by the Montreal Protocol although the mechanism does exist for its potential regulation (Kanter, et al., 2013). Global emissions of N_2O are the combined result of natural environmental processes and anthropogenic activities. The accounting of anthropogenic N_2O emissions remains imprecise as a result of difficulties in allocating environmental emissions that may be anthropogenic in origin although they are generally believed to be in the order of 40% of total emissions (USA Environmental Protection Agency, 2010), with agriculture accounting for ~75% of anthropogenic emissions (Mosier, 2014). For each anthropogenic source of N_2O there are large range brackets because methods of estimating global N_2O budgets, such as the IPCC methodology (Intergovernmental Panel on Climate Change, 2006), require extrapolation of emissions rates and emissions factors across diverse geographical regions and industries.

According to IPCC methodology, about 1% of fertiliser-N added to soils during agricultural production is directly emitted to the atmosphere as N_2O (Intergovernmental Panel on Climate Change, 2000). Total nitrous oxide emissions from fertiliser are commonly estimated at the farm gate using an estimate generated by CFT (Hillier, et al., 2011). At present there is no calibrated emissions dataset for Australian grown processing tomatoes.

Losses of N_2O from fertiliser applications are known to differ depending on the form of fertiliser applied and its method of application (Burger and Venterea, 2011; Eichner, 1990; Velthof, et al., 1996). Studies on the losses of N_2O in single cropping systems are required to generate an accurate picture on the actual losses to the atmosphere of N_2O (Dalal, et al., 2003). At present, the only directly comparable published study of N_2O emissions in field grown processing tomatoes irrigated by subsurface dripline was published by Kennedy, et al. (2013) who found N_2O emissions from processing tomato crops under drip irrigation were reduced by 69% when fertiliser was applied using subsurface drip irrigation when compared to furrow irrigation.

The study presented examined N_2O emissions from processing tomato crops in Australia. The aim of the study was to quantify N_2O emissions over the course of a growing season and to ascertain which management practices and weather events resulted in large N_2O fluxes.

Methodology

Four commercial processing tomato (*Solanum lycopersicum*) farms in the Rochester – Echuca-Boort area of Victoria were monitored during the 2014–15 and 2015–16 growing seasons. The four farms varied in soil properties. The soil organic matter of farm 1 was 22–56% higher in the topsoil, compared to the other farms. Farm 1 was a new block with this the first tomato crop grown; farms 2–4 had previously grown tomatoes. Farm 1 had the highest residual soil nitrate-nitrogen levels prior to fertiliser application and applied the greatest proportion of fertiliser nitrogen as a pre-plant basal fertiliser; 57% compared with 21–32% at the other three farms.

Cultivation across the four farms involved disc, power harrow and deep ripping prior to bed forming. All farms applied metham sodium (192 L ha^{-1}) for 15–27 days before planting. Irrigation was applied using only sub-surface drip, with a single drip line buried 25cm along the middle of the bed.

The processing tomato crop was established using seedling transplants (farms 1–3) or direct seeding (farm 4) of a single row, directly above the single sub-surface drip line. Immediately following planting, irrigation was applied through the sub-surface drip system until water reached the soil surface. During the remainder of the growing season drip irrigation was applied on demand with 43–79% of the nitrogen applied as fertigation. There were no significant in-season rainfall events (>30 mm) during 2014–15.

The crops were mechanically harvested and yield (tonnes ha^{-1}) measured at each of the four farms.

Nitrous oxide measurement

Eight static chambers (installed volume of 7.3L; four on the shoulder of the bed and four in the centre of the bed directly above the sub-surface drip line) on each farm were used to monitor nitrous oxide emissions. Sampling for nitrous oxide focused on cultivation and basal fertiliser application, planting and fertigation events. At each sampling date, gas samples were taken at 0, 30 and 45 minutes after the chamber was sealed. Gas samples were transferred into 10ml Exotainers and sent to the laboratory for nitrous oxide analysis using gas chromatography. Sample nitrous oxide concentrations were then used to calculate the flux from the soil (g N_2O-N ha^{-1} day^{-1}). The measured nitrous oxide emissions were used to calculate crop emissions on an area basis (kg N_2O-N ha^{-1}) and as an emission intensity (g N_2O-N tonne $fruit^{-1}$).

Nitrous oxide estimation from models

The project used the Cool Farm Tool (Hillier et al 2011) and the Intergovernmental Panel on Climate Change (IPCC, Smith 2001) default emission factor to estimate nitrous oxide emissions. Based on these estimates, crop emissions on an area basis (kg N_2O-N ha^{-1}) and as emission intensity (kg N_2O-N tonne $fruit^{-1}$) were calculated.

Outputs

Scientific papers

K. Montagu, S. Moore, L. Southam-Rogers, N. Phi Hung, L. Mann and G. Rogers (2016) "Low nitrous oxides emissions from Australian processing tomato crops – a win for the environment, our health and farm productivity", *Acta Horticulturae* **(Appendix 1)**

Best practice guide

A best practice guide on how to manage nitrogen loss was published as a factsheet: "Growing practices to reduce soil nitrous oxide emissions and nitrogen loss from processing tomatoes". **(Appendix 2)**

Presentations

Paper presented at the **XIV International Symposium on Processing Tomato - XII World Processing Tomato Congress** in Santiago (Chile) March 6-9 2016. (**Appendix 3)**

Paper presented by Liz Mann in June 2014 at the **XIII International Society for Horticultural Science Symposium on the Processing Tomato** in Sirmione, Italy.

Australian Processing Tomato Research Council forum presentation 2013. **(Appendix 4)**

Australian Processing Tomato Research Council forums in presentation 2014. **(Appendix 5)**

Australian Processing Tomato Research Council forums in presentation 2015. **(Appendix 6)**

Australian Processing Tomato Research Council forums in presentation 2016. **(Appendix 3)**

Articles

The Weekly Times in June 2015. **(Appendix 7)**

The "Shepparton News" in April 2013. **(Appendix 8)**

An article on the full details of the project was written for the September 2015 edition of the *Australian Processing Tomato Grower* magazine. **(Appendix 9)**

An article on the full details of the project was written for the September 2013 edition of the *Australian Processing Tomato Grower* magazine. **(Appendix 10)**

Radio

Radio interview by Liz Mann in June 2014 discussing the opportunities on the international market of producing a lower conversion factor for the Cool Farm Tool measuring greenhouse gas emissions on farm: http://www.abc.net.au/news/2014-06-30/tomato-growers-keep-demand-alive/5560774 **(Appendix 11)**

Outcomes

Three outcomes were achieved.

1. The project successfully benchmarked the greenhouse gas emissions intensity of processing tomato production at four typical farms in Victoria. Measured crop nitrous oxide emissions were low ranging from 0.23 to 0.45kg N_2O-N ha^{-1} at three of the farms, and 1.51kg N_2O-N ha^{-1} at the fourth.

2. The full set of data collected by the projected has been forwarded to the Sustainable Food Lab, USA for the calculation a new conversion factor for the Cool Farm Tool specifically for Australian processing tomato growers. The revised conversion factor will recognise Australian producers' low nitrous oxide emissions, which are lower than both the Californian and global averages.

3. The project has identified soil management practices which can be used to reduce N_2O emissions. This was achieved by monitoring the different practices across four commercial farms. The variation in nitrogen fertiliser management, soil organic matter, planting practices allowed the project to identify key practices to reduce N_2O emissions. These have been summarised in the factsheet "*Growing practices to reduce soil nitrous oxide emissions and nitrogen loss from processing tomatoes*" (Appendix 2). The approach differed from what was initially envisaged by the project following feedback from the APTRC, as reported in milestone 103. This resulted in less emphasis on imposing different soil management treatments, with more emphasis placed on understanding the impact of differing industry practice across the four farms.

Did the project achieve additional benefits?

The project highlighted the role of metham sodium in reducing N_2O emissions during the high risk period of planting/wet up. During the growing season, nitrous oxide emissions were measured to be four times greater in the absence of metham sodium. The ability to control nitrous oxide emissions outside of the growing season is unclear and would require further study.

Are there any outcomes that are likely to be achieved in the longer term as a result of the project?

Data that has been forwarded to the Cool Farm Tool will allow for a lower conversion factor to be applied to Australian tomato producers. This will give Australian growers a marketing advantage of other exporting countries due to their low greenhouse gas emission rates, compared to the Cool Farm Tool estimates.

A best practice guide on minimising nitrogen loss as N_2O has been written and will become a permanent resource for the industry.

Social and environmental impacts – benefits/risks to industry, community and environment – resulting from the project

Australian processing tomato producers will have a competitive edge in global markets once a lower conversion factor is applied to the Cool Farm Tool. As a result of the project, the industry is more aware of the benefits of subsurface drip irrigation and fertigation, and the risks of flood irrigation and basal fertiliser application.

Evaluation and Discussion

The effectiveness of project activities in delivering project outputs and achieving the intended outcomes.

The project has produced two growing seasons' of greenhouse gas emissions data from commercial operations (2014-15 & 2015-16). There were technical difficulties in measuring nitrous oxide emissions in the first growing season (2013-14). As a result, the project was extended to include the additional growing season of 2015–16. The two seasons 2014–15 and 2015–16 have produced very robust data under commercial field conditions on nitrous oxide emissions from processing tomato production in Australian.

The data on greenhouse emissions has been made available to the Cool Farm Tool, which is managed by Sustainable Food Lab, USA and used to estimate greenhouse gas emissions from food production. The data has also been made available to the South Australian Research and Development Institute (SARDI) for incorporation into the Vegetable Carbon Calculator.

Feedback on activities and the quality and usefulness of project outputs. Detail of how and when feedback was sought and how this feedback was incorporated into the project.

Yearly presentations were held at APTRC research and development meetings in Echuca, Victoria. The meetings were used for an open dialogue between all stakeholders and direct feedback was collected. As noted in Milestone Report 103, It was decided that the focus of the project should be on measuring and benchmarking the greenhouse gas emissions, particularly nitrous oxide. It was expected that N_2O emissions would be low among Australian growers and that a robust set of data would provide proof that Australian growers' use of drip irrigation and fertigation contributes to a low greenhouse gas footprint for the industry.

Demonstrate and quantify changes resulting from the project.

The project established that greenhouse gas emissions during the growing season for tomatoes for processing were very low. The project data provides proof that the industry adoption of drip irrigation and fertigation results in lower emissions when compared to the expected emissions from the Cool Farm Tool, which is based on average global greenhouse gas emissions. The project demonstrated that processing tomato industry already is performing very well in regards to the greenhouse gas emissions during crop production and that it is very competitive in the global market for sustainable food production.

Furthermore, it was shown that emissions vary significantly across the four commercial sites that were measured. This is thought to be a result of different proportions of nitrogen applied as either basal fertiliser or fertigation through drip irrigation lines. It appears that applying 70-80% of the nitrogen fertiliser via fertigation reduces the risk of N_2O emissions.

The project identified that metham sodium is a major factor in reducing nitrous oxide emissions during the initial wet-up at sowing, which is the highest risk period for N_2O emissions. In 2015-16 an experiment was established to monitor N_2O emissions when metham sodium was not applied. This ability of metham sodium to reduce N_2O emission highlighted the inadvertent role metham sodium application was playing in reducing N_2O emissions during the high risk planting period. If the industry is to reduce its use of metham sodium particular attention will need to be paid to the planting period so that N_2O emissions do not dramatically increase.

The learning from the project and overall relevance to industry.

The key learnings of this project are that:

- Emissions are lower than the Cool Farm Tool assumptions. N_2O emissions across the growing season were overestimated 10–12 times for three of the farms that used applied a high proportion of nitrogen as fertigation.
- Emission intensity is very low for processing tomatoes production in Australia at between 0.001kg N_2O-N and 0.011 kg N_2O-N emitted per tonne of fruit.
- Metham sodium can reduce N_2O emissions during the heavy irrigation when the crop is planted.

Recommendations

It is recommended that 70-80% of nitrogen fertiliser be applied via fertigation through subsurface drip irrigation to reduce nitrous oxide emissions.

The low intensity emissions of Australian processing tomatoes should be promoted as an advantage when compared to other countries and other food productions.

Further studies should:

1. Examine how crops can be established using subsurface drip without excessive irrigation, or "wet-up", at planting. Saturation of the soil leads to accelerated loss of nitrogen as N_2O.
2. Determine how long after the application of metham sodium is N_2O emissions reduced and what are the impacts on other aspects of soil biology.
3. Assess the impact of alternatives to metham sodium on N_2O emissions.
4. Consider the impact of management practices which increase organic matter input on N_2O emissions.
5. Determine the N_2O emissions outside the tomato growing period (fallow/winter crops) and options for reducing emissions.
6. Consider how soil carbon is affected by tomato production and thus understand the whole production system impact on greenhouse gases.

Scientific Refereed Publications

K. Montagu, S. Moore, L. Southam-Rogers, N. Phi Hung, L. Mann and G. Rogers, "Low nitrous oxides emissions from Australian processing tomato crops – a win for the environment, our health and farm productivity", *Acta Horticulturae*.

Intellectual Property/Commercialisation

No commercial IP generated

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Appendices

Appendix 1 Tomato nitrous oxide emissions - Paper.pdf

Appendix 2 Nitrous Oxide Factsheet_AHR final.pdf

Appendix 3 World processing tomato conference presentation 2016.pdf

Appendix 4 2013 APTRC Presentation.pdf

Appendix 5 2014 APTRC presentation.pdf

Appendix 6 2015 APRTC presentation.pdf

Appendix 7 Weekly Times 26June2015.pdf

Appendix 8 Shepparton News Arpil 2013.docx

Appendix 9 APTRC Magazine Article 2015.pdf

Appendix 10 Tomato Topics.pdf

Appendix 11 Radio interview.eml