Australian Government
Department of Agriculture

POLICY DELIVERY | **ACTION ON THE GROUND 1**

Application ID: AOTGR1-035

FINAL REPORT: **IMPROVED NITROGEN EFFICIENCY ACROSS BIOPHYSICAL REGIONS OF THE EYRE PENINSULA**

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FINAL REPORT

PROJECT TITLE:

Improved nitrogen efficiency across biophysical regions of the Eyre Peninsula

PROJECT DESCRIPTION

This project will measure nitrous oxide (N_2O) emission levels from wheat grown in rotation with canola, pulses and legume pastures in key biophysical regions of the Eyre Peninsula (EP); while assessing best management practices that local farmers can adopt to minimize N_2O losses from the use of synthetic fertilizers through the use of cost effective alternative nitrogen (N) sources.

EXECUTIVE SUMMARY

Nitrous oxide (N_2O) is a greenhouse gas (GHG) which lasts in the atmosphere for 121 years and has a global warming potential (GWP) 265 times that of carbon dioxide over a 100 year timescale (IPCC, 2014). . Agriculture accounts for approximately 80% of Australia's nitrous oxide emissions (Dalal et al., 2003) This is primarily a result of using nitrogen-based fertilisers on crops and pastures, and the mineralisation of soil organic matter, both leading to the accumulation of soil nitrate (NO_3^-) an important ingredient in N_2O production. The N_2O losses represent a loss of N from cropping soils which can reduce farmer profits and contribute to increasing GHG emissions and global warming and ozone depletion.

Key findings:

- N_2O fluxes were higher at Wanilla (lower EP) than at Minnipa Agricultural Centre (MAC), upper EP, and at both sites the emissions were higher over a 2 year canola wheat rotation than a legume wheat rotation
- Results show that there was a response of N_2O emissions to the nitrogen applied post sowing, in the canola phase of the 2-year rotation.
- High pre-seeding soil mineral N resulted in peak N_2O fluxes at both sites following a significant summer (2014) rainfall event.

The N_2O emission data from both sites show that emission levels in low rainfall farming systems appear to be lower than levels in medium-high rainfall farming systems, and this is consistent with other studies done in dryland low-medium cropping systems (Barton et al, 2008; Officer et al, 2015; Schwenke et al, 2015). One of the objectives of this project was to confirm or oppose current perceptions that farming systems

produce low N_2O emission from EP soils (Grace pers. comm.), then use that knowledge to develop principles that can be considered in managing N_2O losses in low-medium rainfall farming systems.

Wheat yields following canola, a pulse and legume pasture were not significantly different ($P<0.05$) and ranged from 2.6 – 2.9t/ha at the low rainfall MAC site, but higher ($P<0.05$) following lupins (2.9t/ha) than following canola (2.7t/ha) at Wanilla (highest N_2O flux site). Integrating a legume into cropping systems on the EP did not compromise wheat yields, reducing synthetic N requirements and ultimately reducing N_2O emissions.

Future research:

- *N_2O emissions from the soil are by products of two key processes: nitrification and denitrification. Denitrification occurs in waterlogged soils and since waterlogging is an issue in the lower EP (winter), more work needs to be done to quantify how much synthetic N is lost as di-nitrogen (N_2) gas in these duplex mildly acidic soils; and also how much is lost through leaching.*
- *The peak in N_2O fluxes at both sites coincided with a marked reduction in soil organic carbon, (165 – 678gC/ha/day to 29 – 55gC/ha/day at Wanilla; and 129 – 181gC/ha/day to 2 – 13gC/ha/day at MAC) and high soil mineral N (Table 2), hence more work needs to be done to understand the link between microbial mineralization and N_2O emissions in low-medium rainfall farming systems.*

METHODOLOGY

Two trial sites were selected representative of the low and medium rainfall zones of the EP region of South Australia. One trial site was located at Minnipa Agricultural Centre (MAC) (upper EP) and the other near Wanilla (lower EP). The average growing season rainfall (GSR) at Wanilla is 400 mm and the soil type is a duplex sand over clay loam with 1.2 % organic carbon content. Average GSR for MAC is 241 mm and the soil type is a calcareous red sandy loam with 0.9 % organic carbon content. The trials were a randomized block design consisting of four treatments replicated three times and completed over a 2-year rotation (Table 1).

Gas samples were collected before and after sowing, before and after in crop nitrogen applications and following significant rainfall events. The gas samples were collected from individual sealed PVC static chambers (325 mm high x 250 mm diameter) fitted with gas extraction septa. 20 ml gas samples were withdrawn from the chambers using a syringe, injected into pre-flushed and pre-evacuated vacuumed vials.

Table 1 Trial details

	2013		2014	
	Minnipa	Wanilla	Minnipa	Wanilla
Total annual rainfall (mm)	334	600	407	437
Growing season rainfall (April – October)	237	480	290	368
Crops	canola (Stingray), annual medic (Angel), peas (Twilight)	canola (Hyola 575CL), sub-clover (Dalkeith), lupins (Mandelup)	wheat (Mace)	wheat (Mace)
Sowing date	30-Apr	17-May	12-May	11-May
Sowing fertiliser	DAP @ 50kg/ha	DAP @ 80kg/ha [1]46kg N/ha	DAP @ 50kg/ha	DAP @ 80kg/ha [2]28kg N/ha
In crop fertiliser	[1]23kg N/ha (21 June) [1]23kg N/ha (29 July)	[1]46kg N/ha (26 June) [1]30kg N/ha (30 August)	[2]21kg N/ha (15 July)	[2]28kg N/ha (18 July)
N_2O sampling dates	2 May, 24 June, 31 July, 2 Sept, 1 Oct, 9 Nov; 26 Jan 2014, 17 Feb 2014	17 May, 26 June, 1 Aug, 30 Aug, 5 Oct, 25 Oct; 15 Feb 2014, 18 Feb 2014	11 April, 14 April, 14 May, 14 July, 18 July, 2 Sept, 15 Dec	30 April, 2 May, 13 May, 10 July, 21 July, 16 Dec

[1] *Fertiliser applied to canola treatments*

[2] *Fertiliser applied to the canola –wheat high input treatment (Canola H)*

On each gas sampling day, lids were attached to the chambers, and an initial gas sample was collected immediately. Subsequent samples were taken every 20, 40 and 60 minutes over a one hour period, resulting in 4 separate gas samples taken from each chamber. Air temperature was recorded from one replicate chamber and soil temperature was measured near the base of the chambers when each gas sample was extracted.

All samples were sent to the University of Melbourne for N_2O and CO_2 concentration analysis. The data from the four gas samples for each gas sampling were converted into a chamber flux by converting each sample to gas density (Harris et al, 2013). Other measurements collected on every gas sampling day included:

- 0 – 10 cm and 10 – 30 cm gravimetric soil water content (mm)
- Soil temperature (5cm)
- 0 – 10 cm and 10 – 30 cm soil samples for mineral nitrogen (NH_4^+ and NO_3^-) analysis.

1. Minnipa

In the first 12 months from May 2013 to April 2014, N_2O fluxes ranged from 0 -0.11g to 38.9g N_2O-N/ha/day and were higher than during the cereal phase of the rotation in 2014 (0g to 4.7g N_2O-N/ha/day). Emissions were higher on the canola treatments and lower on the peas during the first 12 months. The peak in emissions occurred after 17mm of rain (January 2014) and ranged from 28.3g to 38.9g N_2O-N/ha/day (Figure 1), with the highest N_2O fluxes on the canola treatment.

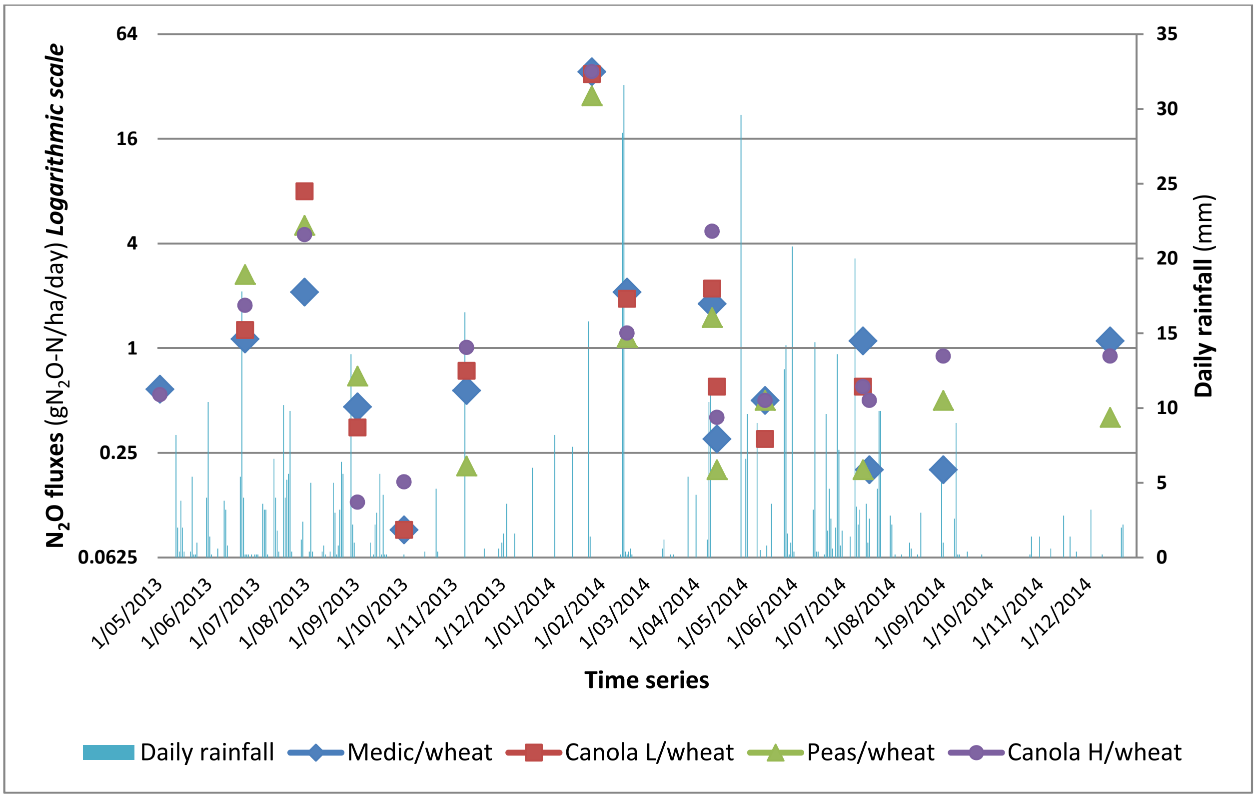

Figure 1 Minnipa N_2O fluxes in 2013/14

**Negative fluxes not shown on the logarithmic scale.*

2. Wanilla

Emissions ranged from 1.1g to 135.5g N_2O-N/ha/day in 2013/14, and were lower in the cereal cropping phase the following season (2014) when emissions ranging from -0.1 to 11.1g N_2O-N/ha/day. N_2O fluxes peaked post-harvest in 2014 after 50mm of rain (13 - 15 February) and ranged from 93.2 to 135.5g N_2O-N/ha/day, with the highest N_2O flux from the high input canola treatment (Figure 2).

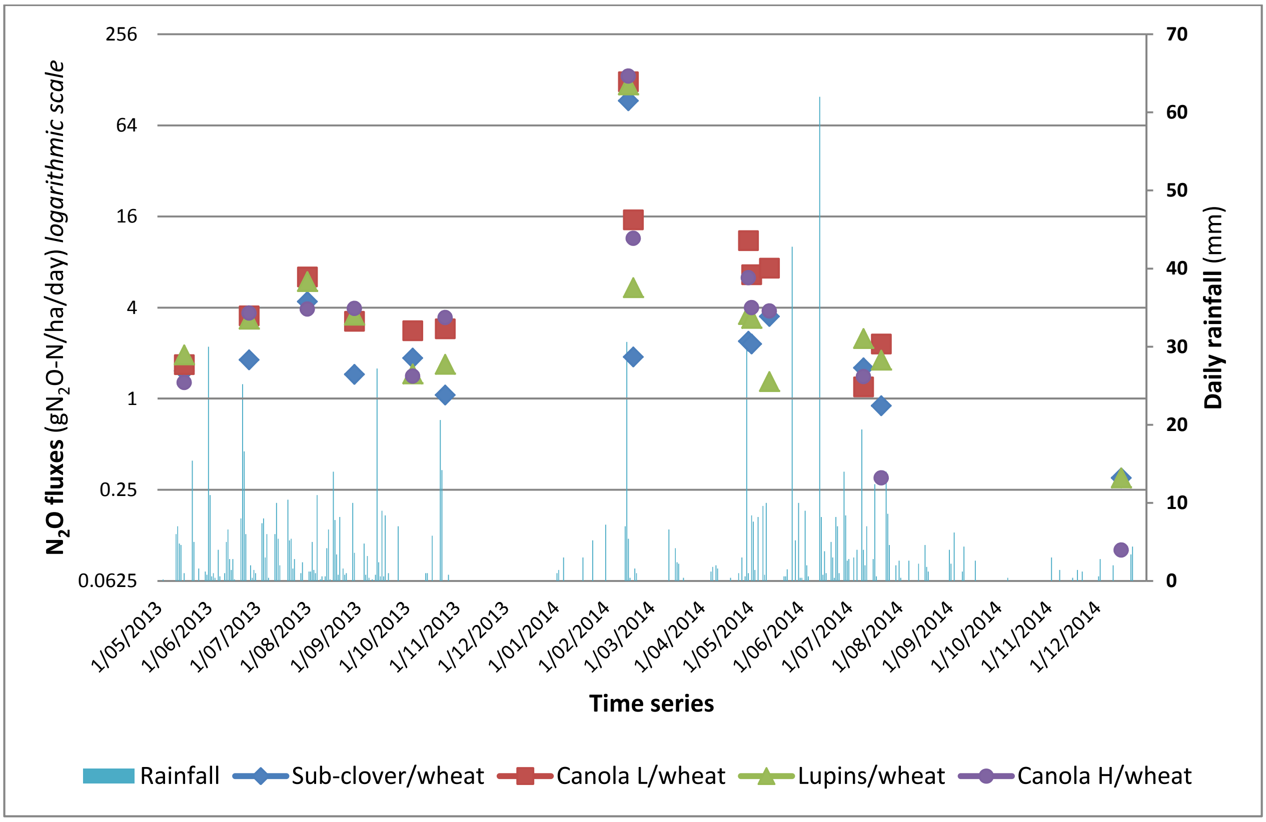

Figure 2 Wanilla N_2O fluxes in 2013/14

**Negative fluxes not shown on the logarithmic scale.*

2014 mean N_2O emissions were significantly higher on the canola - wheat high input treatment (5.7g N_2O-N/ha/day compared to 2.25g N_2O-N/ha/day on the lupins – wheat treatment) at Wanilla, but no significant differences in mean emissions were observed at MAC on all treatments (0.5g to 1.34g N_2O-N/ha/day).

2013 results show an increase in N_2O emissions to in-crop N and moisture. Emissions increased from 1.3g to 7.9g N_2O-N/ha/day at Minnipa and from 3.7g to 6.4g N_2O-N/ha/day at Wanilla, pre and post N application on the canola treatment. However, there was no increase in emissions to in-crop N in the cereal phase in 2014.

The peaks in emissions at both sites occurred after a summer rainfall event (0 – 10cm water-filled pore space percentage ranged from 27 – 32% at Minnipa and 35 – 39% at Wanilla) and associated increase in soil mineral N levels (35 –54mg/kg $NH_4^+ + NO_3^-$ at Minnipa and 68 – 111 $NH_4^+ + NO_3^-$ at Wanilla) (Table 2).

Table 2 Soil carbon, moisture and mineral N on two spring/summer sampling events at Wanilla and Minnipa

Site	Rainfall (mm) - date	sampling date	2013 crop	WFPS 0 - 10cm (%)	NO_3^- (mg/kg)	NH_4^+ (mg/kg)	gC/ha/day
MINNIPA	16mm - 8 Nov	09-Nov-13	canola - L	30.8	24	9	178.0
			canola - H	33.6	18	6	181.0
			annual medic	33.3	18	8	177.0
			field peas	34.0	19	10	129.0
	17mm - 24/25 Jan	26-Jan-14	canola - L	28.1	40	0	4.8
			canola - H	31.7	53	1	13.1
			annual medic	27.6	37	3	4.5
			field peas	32.1	35	1	2.4
WANILLA	35mm - 22/23 Oct	25-Oct-13	canola - L	32.6	20	2	164.5
			canola - H	33.5	18	4	169.0
			sub-clover	28.2	10	2	678.0
			lupins	30.0	25	2	205.3
	50mm - 13/14 Feb	15-Feb-14	canola - L	36.4	91	7	54.8
			canola - H	38.7	88	23	55.0
			sub-clover	35.1	59	9	28.8
			lupins	35.3	97	9	37.9

These figures suggested that most of the N_2O losses probably occurred through the nitrification pathway and not denitrification which occurs under waterlogged conditions, when oxygen supply becomes limited (Dalal *et al*. 2003). 2013 summer peak N_2O fluxes suggest that back ground mineralisation over the fallow period accompanied by significant summer rainfall events can lead to high N_2O emissions irrespective of previous N fertiliser management.

IMPLICATIONS FOR AUSTRALIAN AGRICULTURE

The nitrous oxide emissions measured in these two farming systems, represent an agronomic loss on N from cropping soils. These losses are a limitation to paddock productivity and profitability, even though they are generally low. If we assume that mean N_2O losses for each cropping phase represent mean annual losses; then mean losses for the canola-wheat high input treatment which were 20g and 6g N_2O-N/ha/day would equate to 7.3kg and 2.2kg N_2O-N/ha/year at Wanilla and Minnipa respectively. These losses are in a similar range recorded in a canola – wheat rotation on a black cracking soil in Tamworth, NSW (Schwenke et al. 2015).

Assuming a cost of $560/tonne of urea, N_2O losses of 7.3kg and 2.2kg N_2O-N/ha/year would represent a loss of $7.88 and $2.88/ha/year for Wanilla and Minnipa respectively. While these annual losses appear to be minimal, there could be higher losses of soil N as N_2 especially at the Wanilla site where soils are prone to waterlogging in winter. According to Mike Bell GRDC telecast, for every unit of N_2O we could be losing 40 units of N_2. This would represent a significant agronomic cost e.g. the summer peak in emissions at Wanilla (135.5g N_2O-N/ha/day on canola stubble) would potentially translate to another 5.4kg N/ha lost as N_2.

Since greenhouse gases are reported in carbon dioxide equivalents (CO_2-e), these annual losses are equivalent to 3041kg and 916kg CO_2-e. Using the 2013/14 fixed carbon price of $24.15/tonne (Cleanenergyregulator.gov.au, 2015), the value of N_2O emitted would translate to $73/ha/year and $22/ha/year for Wanilla and Minnipa respectively.

ENDORSEMENT

I Rob Harris am satisfied with the contents of the report, and endorse the reports submission to the Federal Dept. of Agriculture.

Dr. Rob Harris

I, Peter Grace, have reviewed this report and I endorse the reports submission to the Federal Department of Agriculture

Prof Peter Grace, Qld University of Technology

ACKNOWLEDGEMENTS

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Project delivery: South Australian Research & Development Institute (SARDI), Department of Primary Industries Victoria, University of Melbourne.

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